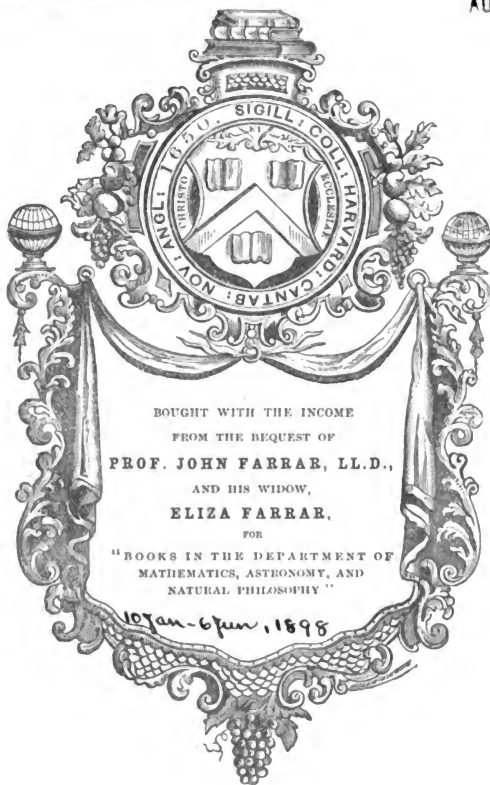


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THE JOURNAL

—OF THE—

FRANKLIN INSTITUTE,

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

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EDITED BY

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mittee on Publications, with the Assistance of Dr. Wm.  
H. Wahl, Secretary of the Institute.

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with the Assistance of

DR. WM. H. WAHL, Secretary of the Institute.

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THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

## THE FRANKLIN INSTITUTE.

*Stated meetings, September 15 and October 20, 1897.*

MR. JOHN BIRKINBINE, President, in the chair.

THE SMOKE NUISANCE AND ITS REGULATION, WITH ESPECIAL REFERENCE TO THE CONDITION PREVAILING IN PHILADELPHIA—IMPROVED FURNACES AND MECHANICAL STOKERS.

THE COXE AUTOMATIC STOKER.\*

MR. MATTHEW C. JENKINS [New York]:—I take pleasure in describing to you to-night the automatic stoker invented by the late Eckley B. Coxe, of Drifton, Pa.

After a series of careful experiments carried on at Drifton, Mr. Coxe decided that for the proper, and at the same time the most economical, combustion of coal, the following conditions were necessary:

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\* Manufactured by the Coxe Iron Manufacturing Company, Drifton, Pa., and New York.

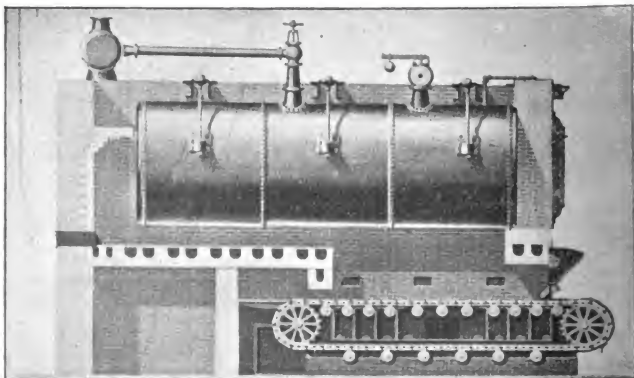
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(1) To ignite the coal and burn it without mixing it with fresh fuel; that is, that fresh fuel should not be commingled with the already partially consumed coal.

(2) To have the furnace so arranged that the combustion should be continuous and uniform; that is to say, when the furnace was in use the condition of the fire would be practically the same at any hour of any day of any week of the year.

(3) To make the work of firing as easy as possible, so that a minimum number of firemen would be employed, and that the whole operation of the furnace would be controlled by an



Coxe mechanical stoking furnace applied to return tubular boiler.

intelligent man who would have more use for his brains than for his muscles.

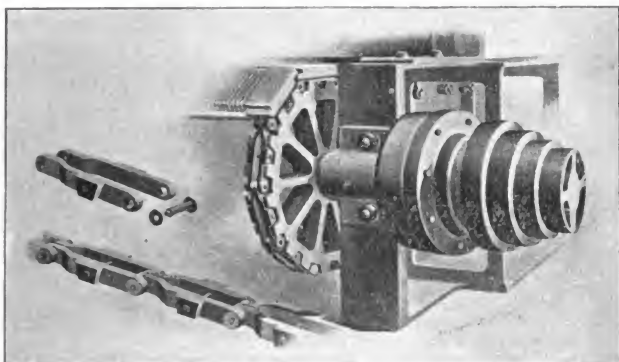
The Coxe automatic stoker was designed to comply with these conditions. It is an endless travelling grate, as shown in accompanying cuts, which receives the fuel at one end, burns it as it moves slowly along, and deposits the ashes at the other end. It was designed originally to burn the smallest sizes of anthracite coal, but handles bituminous as well and with an entire absence of smoke.

To insure complete combustion, and at the same time leave a minimum of free oxygen in the chimney gases, the

fuel, in passing the working length of the grate, is subjected to varying pressures of air. In other words, as the amount of carbon in the bed of fuel diminishes, the amount of air supplied is proportionately diminished to the rear, and thus an excess of air is excluded, and as nearly theoretical combustion as it is possible to obtain by any known means is reached.

One of the most important features of Mr. Cox's invention is the variable air supply, which I will now explain, with the aid of accompanying illustrations.

All the air that enters the fire is conducted into the largest



Detail of chain, showing sprocket and reducing mechanism (Cox's mechanical stoking furnace).

chamber at the center of the frame, and the only air that can enter the adjacent chambers must pass through dampers in the partitions separating these chambers, which are closed at the bottom so that the supply can be regulated to suit existing conditions. In practice, the maximum amount of air is supplied at the center, and this is diminished to a minimum at each end; the dampers being regulated so that the pressure is diminished in each succeeding chamber.

The depth of the bed of fuel is increased or diminished by a gate in the hopper, that can be raised or lowered, as found

necessary. This fuel, on arriving on the grate, is given just sufficient air to ignite it slowly; and, as the ignited coal passes over the succeeding compartments where the air pressure is at the maximum, burns briskly. But when it has lost part of its carbon, it passes over the compartments where the air pressure is again diminished and better suited to the thinner layer of partly consumed coal. The bed continues to diminish in carbon and to be subjected to less air, until finally the hot ashes are cooled off by a very gentle current of air, and are then dumped into the ash-pit at rear end of furnace.

The furnace proper is composed of two side frames, which support the hopper and also the brickwork supporting boiler.



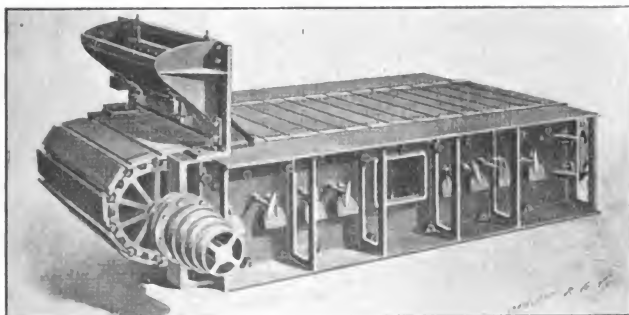
Details showing construction of grate-bars (Coxe mechanical stoking furnace).

They also carry four sprocket wheels, two front and two rear, over which run the chains to which the bar bearers (shown in next view) are bolted. The rollers shown both at top and bottom of frames carry the upper working and the lower returning runs of the grate.

The grate proper is formed of two parts—the “grate keys,” shown detached and in place, and the “bar bearers.” These latter are T-shaped, consisting of a vertical rib and a horizontal plate, and are cast the width of the grate. The horizontal plate is perforated with a number of cone-shaped holes, wider at the bottom than at the top, to admit of the free passage of the air, and have, on their upper surface, a dovetailed rib. At



each end is a lug, which fits in between the links of the chain, and is securely fastened to it by bolts. The upper part of the grate bed consists of the sectional bars, called "grate keys," which are  $7\frac{1}{4}$  inches long by  $\frac{5}{8}$  of an inch wide, and are provided with projections which give an air space of about  $\frac{1}{4}$  of an inch between each pair of these keys. At each end of the dovetailed rib, which is cast on the bar bearer, is a slot, dovetailed at the bottom, which will allow the lower part of the keys to drop into position on the bar bearer. The key is then moved laterally toward the center of the bar bearer and another is dropped into the slot and moved along, until the whole carrying bar is filled, with the exception of spaces occu-



Perspective view of grate (Coxe mechanical stoking furnace):

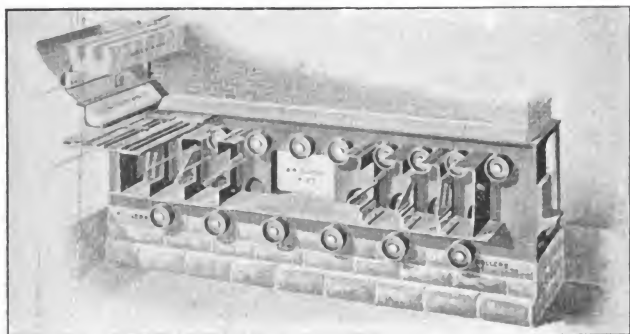
ried by the slots at the ends. To prevent the keys from dropping off, dovetailed pieces, made of cast iron, which fill up the openings so as to make the dovetailed rib continuous, are inserted, and the keys are separated so as to be distributed uniformly through the whole length of the bar bearer, which they fill loosely. Then, as there is no push toward the left hand more than toward the right, and since it requires considerable force to move those on the extreme right hand over to the left, or *vice versa*, there is no tendency for them to drop off. This method of fastening the keys is very simple and perfectly effective.



To remove an imperfect key, a blow with a hammer on the thin part will allow the broken piece to be removed and a new one to be substituted at the end, the one left being moved up to fill the space occupied by the discarded key. The replacing of grate keys does not interfere in any way with the continuous operation of a power plant.

The chains which carry these built-up grate bars are made from drop-forged steel links, all the holes in which are drilled to insure accuracy; and the pins with which these links are riveted are made from cold-drawn steel, so that where strength is essential it is secured absolutely.

It will be obvious that by the slow motion of the traveling



Detail of air pans, etc. (Coxe mechanical stoking furnace).

grate, from 3 to 6 feet an hour, the tendency to get out of order is reduced to a minimum, and that any little unexpected hitch can be attended to and rectified without the slightest interruption of work. The time of exposure of each section while out of use is so long, that needed attention can be given in even a leisurely manner.

The movement of grate is hardly perceptible to the eye, to insure which we use a reducing mechanism, shown in cut, which is a series of differential gears inclosed in a cast-iron case and constantly running in oil, the details of which need not be explained.

The Coxe Stoker can be applied to any of the modern types of boilers. It comes in widths of from 3 to 10 feet, according to the output of the boiler. Another feature is that a plant equipped with the stoker is not necessarily tied down to any one kind of fuel, as the same machine will burn both anthracite and bituminous coal, and the latter, as already stated, without smoke; or mixed coal can be used. This is, of course, a point worthy of consideration, as in case of inability to obtain either kind of coal, through a strike or other cause, a change can be readily made without trouble.

So much for the description; now for the reasons why the Coxe automatic mechanical stoking furnace is a smokeless one. We all know that with the ordinary method of hand-firing with bituminous coal, the smoke is produced only when fresh fuel is added, and not at all after the same is burning briskly; or, in other words, the sudden elimination of the volatile matter contained in the bituminous coal carries off with it a small quantity of solid carbon produced in the incipient distillation of the fuel, and which appears at the top of the chimney, as smoke.

In the Coxe furnace the fresh fuel is ignited very slowly, owing to the variable air supply, and yet, after it is thoroughly ignited and travels toward center of furnace, has ample *air to complete combustion*, as the following analyses of chimney gases will show.

Average of five samples taken during test:

	Per Cent.
Carbonic acid . . . . .	16.22
Free oxygen . . . . .	2.54
Carbonic oxide . . . . .	Trace

#### THE HAWLEY DOWN-DRAFT FURNACE.\*

MR. W. F. TATNALL:—"The Hawley Down-Draft Furnace" consists of an upper, or water grate, carrying coking coal, and a lower, or common grate, upon which the coked coal is burned. The upper grate has a down draft, and the main part of the air supplied for combustion is passed downward

\* Manufactured by the Hawley Down-Draft Furnace Co., Pittsburgh, Pa.

through the fuel upon it. No coal is ever fired directly upon the lower grate.

The coal burning on the upper grate is incandescent at the bottom, or against the tubes, forming the water grate, and black or "green" on the top. The ignition of the gases takes place in the bottom of the fuel on the upper grate, thus producing a high initial temperature, which is needed for a complete combustion.

The water grate consists of charcoal iron 2-inch pipes connected to 10-inch headers. The tubes are set on an incline, lengthwise of the boiler, sloping towards the front, while the headers are set transversely. The front header is connected to that part of the boiler containing the coldest water, while

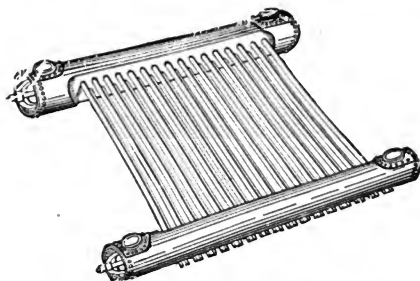


FIG. 1. The Hawley furnace water-grate.

the back header is connected to that part containing the hottest water, at or below the water line. In this way, through the heat given by the fires, a strong circulation of water is induced through the water grate bars, which protects them from burning. The furnace adds to the heating surface of the boiler. Each square foot of heating surface in the water grate has as much evaporating capacity as 5 square feet of the average heating surface of the boiler. The result of this increase in surface is felt in an increase in capacity, or in the total amount of water that may economically be evaporated with a given draft and fuel.

Brass plugs are provided in the front header, opposite each tube, and hand-holes are placed in each header. Through

these openings each tube and header may be examined and cleaned when needed. Blow-off pipes are connected to the headers for removing any collection of mud.

*Principles of Combustion.*—To secure the good combustion of a bituminous coal, it is necessary to have the following conditions:

- (1) A high furnace temperature.
- (2) A gradual and constant distillation of the volatile matter in the coal, and its thorough admixture with air under conditions favorable for the ignition of the gases.

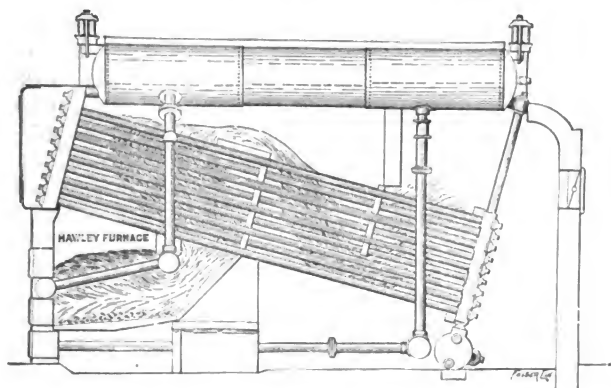


FIG. 2.—The Hawley furnace applied to horizontal water-tube boiler with sectional headers.

- (3) The employment of no more air than is needed to thoroughly burn the fuel.

- (4) The burning of the fuel in the furnace away from the cooling surface of the boiler or other user of heat.

To secure economy in the use of a fuel, it is necessary to not only have good combustion, as just noted, but also to—

- (1) Prevent loss of heat by radiation, as far as is possible.
- (2) To have the temperature of the gases discharged to the chimney reduced to as low a degree as is consistent with the draft required for combustion. This can only be done by hav-

ing clean absorbing surfaces of ample area, and a high initial temperature.

To keep the heat-absorbing surfaces clean, it is not only necessary that they should be free from scale or other non-conducting deposits, but also that the hot side of the surfaces should be free from accumulations of soot. This can be done by so burning the fuel as to produce smokelessness. It is, therefore, evident that all of the conditions just enumerated should hold, and that the formation of smoke should be prevented.

The Hawley furnace meets all of these requirements. Its fire is at an intense heat. The gases distilled from its upper grate pass away at a high heat, thoroughly mixed with the oxygen needed for combustion, and are burned between the two grates, over the bed of incandescent coke lying on the lower grate, and away from the cooling surface of the boiler. The furnace loses less heat by radiation than is found with common furnaces, as has been shown by a number of accurate tests. By burning the gases in the furnace, at a high heat, it follows that the gases passing into the stack are at a lower temperature than is obtained with a common furnace. This was shown by two tests made recently in Philadelphia burning the same fuel, with the same fireman, the boiler being run at about the same rate of evaporation on each trial.

Kind of furnace . . . . .	Hawley.	Common.
Heat units absorbed in steam-making per pound of dry coal . . . . .	11,225	9,767
Temperature of gases in chimney, degrees F. . . .	458	663

*Smokelessness.*—The smokelessness of the Hawley furnace is well established. It practically makes no smoke because the combustion conditions are so nearly perfect that smoke is not formed. It is in no sense a smoke consumer. The city of Pittsburgh has had a salaried official observing the chimneys of its water-works boilers, equipped with Hawley furnaces, during the daytime, continuously for the past eighteen months. He finds that smoke is formed not to exceed 2 per cent. of the time, notwithstanding the fact that the fuel used is much more volatile than that sold in this market, and that the

boilers at times develop as much as 100 per cent. excess capacity. The results of these observations are public property, and may be seen at the office of the Director of Public Works. Such a record means smokelessness.

To further show that this furnace is smokeless, it may be stated to the Institute that it has been officially adopted by the cities of Chicago, Buffalo, Milwaukee, Toronto, Knoxville, Pittsburgh, St. Louis, New Orleans and Detroit for their

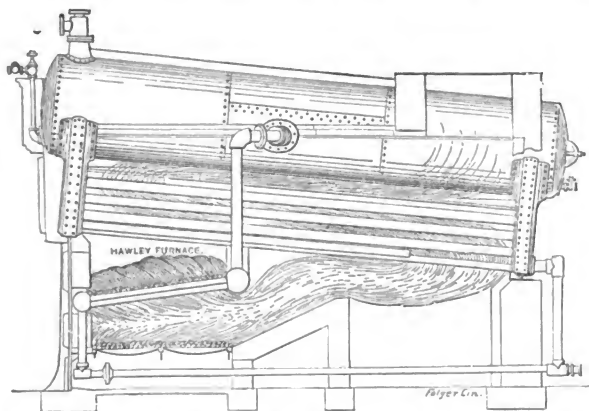


FIG. 3.—The Hawley furnace applied to a horizontal water-tube boiler with open headers.

municipal water or electric plants for the purpose of abating the smoke nuisance.

It may further be stated that the United States Government, which has heretofore burned high-priced grades of anthracite coals in order to avoid making smoke, has been enabled to save, in many instances, as much as 50 per cent. of its fuel costs, by burning bituminous coal in Hawley furnaces, at its plants in a number of important public buildings in Washington, Philadelphia, Baltimore, New York, Omaha and elsewhere.

The loss due to smoke from chimneys is not in itself expensive, but it is absolute proof of bad combustion, showing that

the volatile gases have not been ignited. The loss due to the passing away of distilled gases, rich in hydrogen, sometimes amounts to as much as 20 per cent. It may be said, however, that the absence of smoke is not a positive indication of economy. It is to be particularly noted that the Hawley furnace burns the rich volatile matter distilled from the coal, as this matter is liberated, and burns these gases without smoking.

The furnace is economical because—

(1) There is no loss in fuel or capacity during the cleaning of fires. The coke on the lower grate is allowed to burn out and the ashes are then withdrawn. The grate is then covered with new coke rattled down from the upper grate. The time of cleaning does not exceed two minutes for moderate-sized grates. The slicing of the upper grate opens its fire and increases the rate of combustion. The upper grate does not require cleaning unless a badly clinkering coal is used, in which case the clinker is loosened by a bar and pulled out without uncovering the grate. In this way the loss of from 3 to 5 per cent. in economy when cleaning fires, by cold air rushing into the furnace, is obviated, and the capacity developed is actually increased.

(2) There is no loss in the ash-pit, since any coal not completely burned on the upper grate is caught on the lower grate and consumed. The coke fire on the lower grate never clinkers with the coals obtained in this market.

(3) No cold air is allowed to come in contact with the heating surface of the boiler. The furnace temperature remains constant, and there is no change in the temperature of the gases in the tubes. This uniformity of expansion, and absence of sudden contractions, prolongs the life of the entire boiler setting as well as of the boiler.

(4) The hydrogen in the coal is worth 4.28 times as much as the carbon, pound for pound. The burning of hydrogen and other gases in the Hawley furnace is the chief cause of its efficiency.

(5) The circulation of water in the boiler is increased by the Hawley furnace. Freedom of circulation is needed not

only for life and durability, but is also important from an economical view.

(6) The practice of coaling heavily at long intervals, so commonly followed by ordinary firemen, with ordinary furnaces, is wasteful in fuel. With the Hawley furnace, on the contrary, it is of no disadvantage, as it is impossible for the gases from the coal to reach the cooling surface of the boiler until they have been ignited by the fires of the furnace, through which they must pass, as they have no other exit. No coal is wasted or burned with indifferent economy in the Hawley furnace so long as the grates are kept covered.

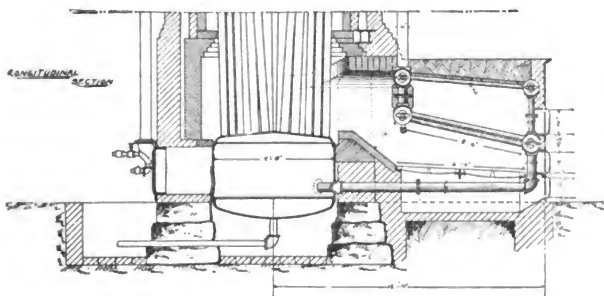


FIG. 4.—Hawley furnace applied to a vertical water-tube boiler.

(7) The coal used in banking a fire over night, for a plant run only during the daytime, is twice as great with a common as with a Hawley furnace. The time required for getting the fires in shape and for getting the boiler under full steam after banking, is least with the Hawley furnace.

(8) In the best modern plants equipped with common furnaces the evaporation per pound of bituminous coal is from 10 to 20 per cent. less than is readily obtained in the same installation after applying the Hawley furnaces. The difference between what is commonly obtained with such plants by the two kinds of furnaces, is shown by the following tests, made at a plant in this city, where the same fuel was burned under the same boiler, the fires being operated by skilful men.



and the trials made under the supervision of experts representing both the furnace company and the owner of the boiler:

Kind of grate . . . . .	Common.	Hawley.
	Per Cent.	Per Cent.
Efficiency of boiler and furnace . . . . .	63.9	79.6
Heat lost in chimney . . . . .	20.8	17.3
Heat lost in imperfect combustion . . . . .	5.7	0.3
Lost in ash and radiation . . . . .	10.6	2.8
	Horse-Power.	Horse-Power.
Nominal rating of boiler . . . . .	100	100
Boiler capacity developed . . . . .	269	287

*Capacity of Boiler.*—The capacity of a boiler has been arbitrarily assumed by different builders to be a certain number of square feet of heating surface to the horse-power. One

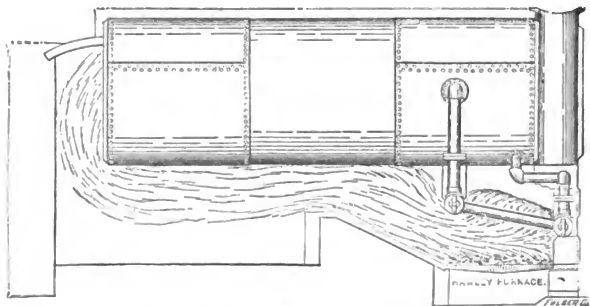


FIG. 5.—Hawley furnace applied to horizontal fire-tubular boiler.

builder of stationary boilers sells his product on 5 square feet to the horse-power, while another sells 15 square feet. A marine boiler develops a horse-power on from 2 to 4 square feet. Again, one builder will proportion his boiler to develop its nominal rating by burning 10 pounds of coal an hour to the square foot of grate area, while a marine boiler often burns from 40 to 50 pounds, and a locomotive boiler burns as high as 120 pounds.

Some Philadelphia manufacturers and steam users object to what they term forcing their boilers, on account of their inexperience with bituminous coal. They are familiar with anthracite coal, which cannot be burned economically at high

rates of combustion. If the rate of running a boiler to produce maximum economy has been determined for a particular boiler equipped with a common grate, the application of a Hawley furnace with the same boiler will permit 30 per cent. more capacity to be developed at the point of maximum fuel economy.

The Hawley furnace permits the economic capacity of a boiler to be raised without impairing the safety or life of the same, or its setting, about as follows, with proper draft conditions:

Nominal rating, 100 horse-power . . .	Relative efficiency . . .	80
Developed capacity, 125 " . . .	" " " . . .	85
" " 150 " . . .	" " " . . .	90
" " 175 " . . .	" " " . . .	100
" " 200 " . . .	" " " . . .	90

In this table, it is shown that the point of maximum economy is at about 75 per cent. excess capacity. The so-called *forcing* of a boiler begins when the evaporative efficiency shows a decline. A stationary boiler thus operated, is not forced to anywhere near the capacity of a locomotive or marine boiler, and its safety or life is in no way imperiled. The Hawley furnace obtains this showing because of its high initial furnace temperature, perfect combustion of the fuel (effected in the furnace and away from the cooling surface of the boiler), and low temperature of gases in the chimney.

The engravings shown herewith exhibit respectively:

*Fig. 1*, the Hawley furnace water grate; *Fig. 2*, the Hawley furnace as applied to a horizontal water-tube boiler having sectional headers; *Fig. 3*, the Hawley furnace as applied to a horizontal water-tube boiler with open headers; *Fig. 4*, the Hawley furnace as applied to a vertical water-tube boiler; *Fig. 5*, the Hawley furnace as applied to a common horizontal fire-tubular boiler.

#### THE MURPHY AUTOMATIC SMOKELESS FURNACE.\*

MR. O. D. COTTON [Detroit, Mich.]:—I need not tell you that the representatives of the "Murphy Automatic Smoke-

\* Manufactured by the Murphy Iron Works, Detroit, Mich.

less Furnace" appreciate the kindly courtesy of an opportunity to present before this body the principles, construction and operation of the furnace.

One of the greatest difficulties in the way of the general successful introduction of this invention has been the fact that a furnace, although the basis of the successful operation of all steam plants, has not usually received the attention its importance justifies, I might properly say, demands. I find it a quite common practice by those who give attention to the

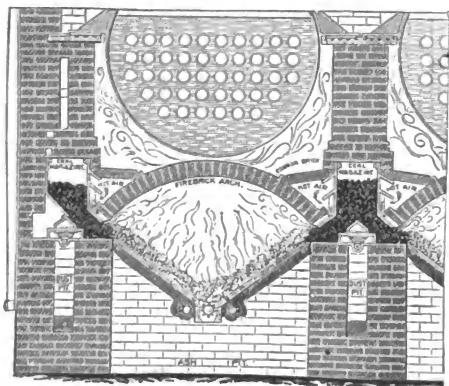


FIG. 1.—Cross-section showing Murphy automatic smokeless furnace applied to horizontal tubular boilers.

science of steam production and power to exercise much thought and care in the choice of both the engine and the boiler, but to give scarcely any attention to the furnace. In other words, the scientific and practical elements in the *application* of steam have overshadowed, and so prevented proper attention being given to, the method of burning the fuel—the most important factor in the cost of *steam production*.

The Murphy automatic furnace is unlike any other furnace, in that it is unique in nearly every feature necessary to its successful operation.

I will not here detail all the stages in the perfection of this

invention. It will suffice to say the most important stage was reached when Mr. Murphy conceived the idea of the mechanical feeding of the coal, coking it as it entered the fire-box, and burning the volatile combustible instantly and completely, thus doing away with smoke.

His furnace was then fed and cleaned mechanically, but by hand-power by use of a wrench. He soon found the average fireman could not be depended upon to stoke the coal, or to clean the fires with constant regularity, and then devised the automatic engine, gears and connections, substantially as now used, and the furnace then became a decided mechanical success. Commercial success, however, was yet to be attained. The high cost, as compared with the usual fronts and grates, was a serious, almost prohibitive difficulty, and he tried to cheapen cost by making a front feed on the same general lines, but after much time and not a little money had been expended, found there was not sufficient coking capacity to that style, nor enough economy to warrant the extra outlay for a mechanical furnace. He therefore fell back on the original type, and practical experience has shown that success required increased instead of decreased cost, because it was necessary to add to its cost in several details to make it capable of meeting all the requirements of the various and varying conditions of steam-power plants. Within the past two years a valuable improvement, which adds fully \$50 per furnace to the manufacturing cost, has made it more completely automatic in the self-cleaning feature, has added to the capacity per square foot of grate, and also to the durability of those parts exposed to the fire. I am able now to present to you a mechanical automatic furnace that has been tried by every conceivable test of utility, and that has been perfected by the inventor after years of experience and suggestion from practical use, and which, we claim, is the best known smoke preventer under any and all conditions which obtain in steam-power plants. It is the only furnace which is automatically cleaned.

There are many forms of mechanical stokers, but there is but one *automatic* furnace.

The principle of its operation is immediate, rapid combustion by means of a coking and a coke-burning furnace, in which the volatile gases are instantly and continuously consumed in connection with the carbon or coke, producing complete combustion, high temperature and practical smokelessness.

By reference to *Fig. 1* the apparatus will be seen to consist of two boxes or coal magazines set in the wall on either side of the fire box. The bottom or base of these magazines is a heavy plate, made to serve also as a coking plate, over

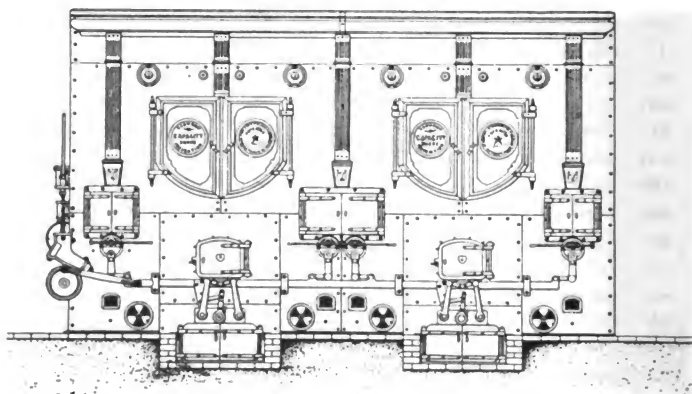


FIG. 2.—Horizontal tubular boiler (front view), equipped with Murphy automatic smokeless furnace.

which the coal is automatically stoked on to the grate. The inner side plate of this magazine has a foot extending inwardly toward the fire, and this forms the base on which a fire-brick arch rests. This foot is ribbed so as to leave a row of small openings the entire length of the arch. On top of this portion of the arch is constructed an air flue, which is supplied with air through flues from the front. The air passes through the flue registers, and through this flue, absorbing heat on its way, and passing down into the fire-box, through these openings at the base of the arch, insures a well-distributed supply of hot

air over and at the point where the volatile gas is being driven off the coal by this coking process.

Large coking capacity is essential to smokelessness, especially when strong duty is required. By this arrangement of coking surface we can coke thoroughly and burn without smoke all the coal the grate surface and draft will burn, the maximum being about 150 to 160 pounds per foot length of coking plate. Our largest size furnace will coke and burn without smoke fully a ton of soft coal per hour, which, we believe, is more than double the quantity any front feed or under feed mechanical or hand-fired style of furnace can coke thoroughly or burn without smoke.

This passage of air through these openings also serves to protect the iron from destructive heat. The operating parts are simple, strong mechanisms and are skilfully adapted to perform the required duty. The stoker boxes are simply inverted open iron boxes, with a rack under each end. The stoker shaft has a pinion geared to each rack, whereby the stoker boxes are worked back and forth on the coking plate, pushing the coal forward to the edge of the coking plate and on to the grates, the upper ends of which rest against the edge of the coking plate. The grates are in pairs, one bar of each pair being stationary, the lower end resting in a notch in the bearer in the center of the furnace and at the bottom of the *V*; the other bar of the pair, being free at the lower end and hinged to the upper end of the stationary bar, is rocked up and down by means of a rocker bar fitted into the lower end of the grate and which runs the entire length of the furnace, from front to rear, on a level with and near each side of the bearer. This constant rocking of every other bar keeps the fine ash sifted out from the bottom of the coals on the grate, thus maintaining a live, clean fire over the entire area of the grate surface, and also, by free draft of air, thoroughly protecting the grates from destructive heat. The clinker and other coarse refuse works its way down to the center of the *V*, where it glides off the end of the grates on to the clinker bar, which is a heavy, round, hollow cast iron bar, having wickers on its surface between the bearings, and, like the grates, supported

by the bearer and, by means of a ratchet gear, kept rotating, thus grinding up and depositing the clinker and coarse refuse in the ash-pit, in suitable condition for removal, either by hand or by mechanical conveyor. The stoker shaft, rocker bar and clinker bar are all operated by means of a flat bar attached to the outside of the front by lugs, which also serve as bearings. By reference to *Fig. 2*, it will be seen that this bar runs across the entire width of the furnace front, and connection with it is made by means of arms and detachable links. The

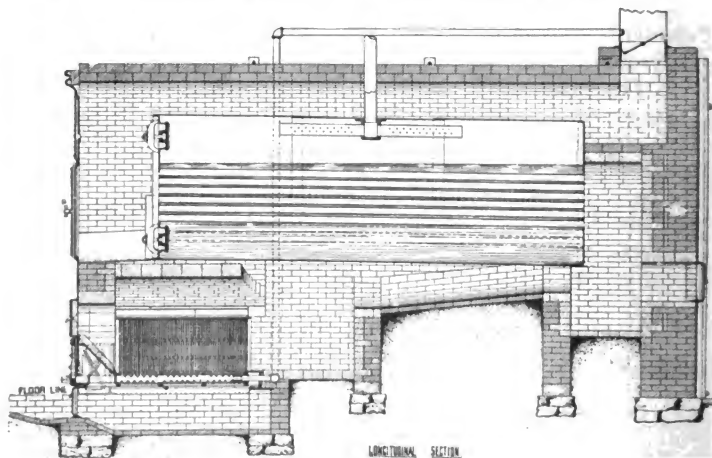


FIG. 3.—The Murphy automatic smokeless furnace, applied to a horizontal tubular boiler.

whole is operated by means of a small upright automatic engine, located on the corner of the boiler or battery setting, the power being transmitted to the automatic bar by means of worms and gears and a connecting bar, as shown. The automatic engine is either single or double, according to size of the battery, or number of furnaces to be operated, has a cylinder 3 inches in diameter, with a 5-inch stroke, and uses but  $\frac{1}{2}$  horse-power of steam per furnace operated.

The fire-box door affords ready access of view or of en-

trance to the interior of the furnace, while the detachable links enable the operator to operate any or all parts by hand with a wrench. You will note that each revolution of the driving gear slides the automatic bar back and forth, stokes a given quantity of coal on to the entire length of the grate surface on each side of the furnace, moves the movable grates up and down once and rotates the clinker bar. Thus, the coal is stoked into the furnace, the ash shaken from underneath the fire and the coarse refuse ground into the ash-pit with every turn of the driving gear, and these various operations so

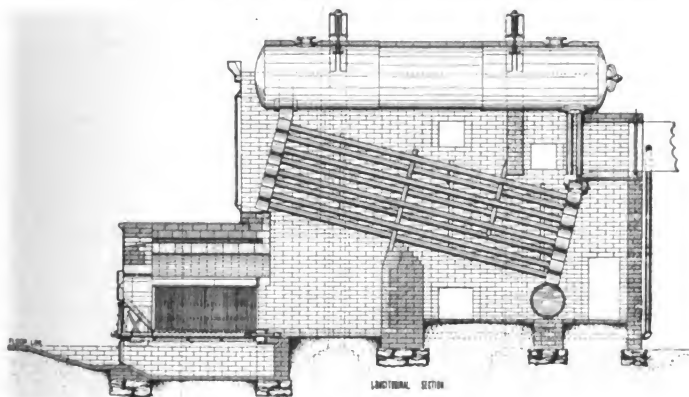


FIG. 4.—The Murphy automatic smokeless furnace, applied to a water tube boiler.

timed and adjusted as to feed the required amount of fuel and preserve a clean live fire, while the coal is slowly and constantly being coked as it enters the furnace, the resultant gas instantly and completely burned to carbonic acid. The coke, passing slowly down the incline of the grate as it is consumed, produces a clean white heat without smoke or soot, and, if the boilers have a proper amount of heating surface of approved form and are properly set to prevent undue radiation, the conditions of the highest practicable efficiency, both as to capacity and economy, should be realized.



In the earlier stages of our experience there was some difficulty in connection with use of low-grade "screenings," to keep the clinker from massing in the center of the furnace over the clinker bar, and thus clogging the furnace, and, in cases where the clinker was "runny" and strong duty required, the clinker bar became overheated and frequent renewal was required. In some such cases, the ratchet motion had to be abandoned and the clinker removed by hand, thus disturbing the evenness of the fire and admitting cold air to such an extent as to reduce the economy and cause more or less smoke at each recurring cleaning.

This difficulty has been satisfactorily overcome by means of our late improvements in the bearer and clinker bar, which, though retaining the original general form, are now so arranged as to admit of a current of cold air passing through the center of the clinker bar, and of a spray of exhaust steam playing on the outer surface of the clinker and grate bars under the bottom of the fire. By this arrangement of air and steam the bearer is protected against heating and consequent sagging, the clinker prevented from sticking to the grates, the clinker bar kept cool, and the action of the steam on the hot clinker cools and makes it brittle, so that it is readily ground through into the ash-pit, thus preventing the former difficulty of clogging, and so rendering the furnace as self-cleaning as it is self-feeding, relieving all the parts exposed to the heat from the former excessive wear, and also requiring less attention and less labor on the part of the fireman.

Another improvement, not shown on the views, is a slight change in the form of the grate bars, which prevents the sifting of the coal through the grates, which, in some cases, where slow coking or semi-bituminous coal is used, has been objectionable. The fire arch extends over the entire surface of the grate area, and is an essential factor in realizing the numerous advantages set forth in what has preceded.

*Fig. 3* shows a longitudinal section of the furnace as applied to the ordinary horizontal fire-tube boiler.

*Fig. 4* shows its application to the most usual form of water-tube boiler. These forms of application can be and are

varied indefinitely to suit special forms of boilers or special conditions of boiler-room space or other fixed requirements.

*Fig. 5* shows one of the many forms of applying coal conveyor, bins, chutes, etc. In the plant shown in this view, the ash-pits are of "hopper" form, and discharge the ash in the ash conveyor in the basement.

*Results.*—The exact results in evaporation depend on so

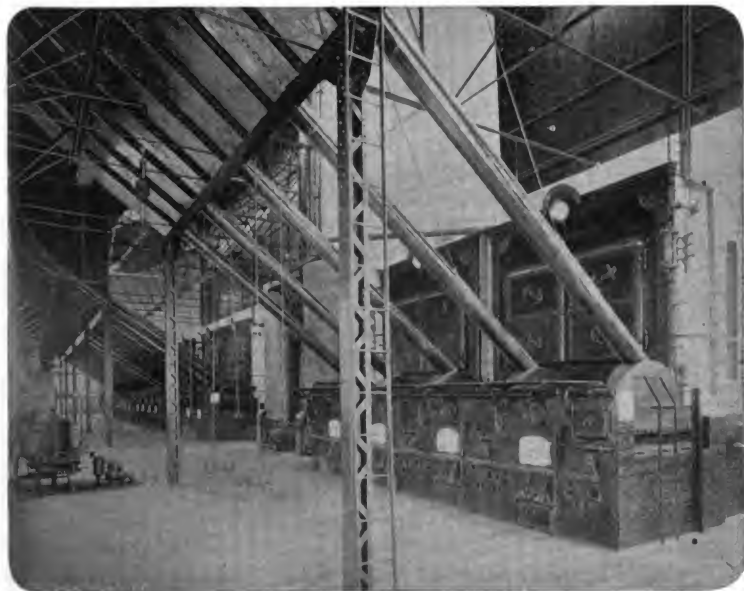


FIG. 5.—Battery of boilers equipped with Murphy automatic smokeless boiler, with coal conveyors, etc.

many variable conditions in the various plants—the grade of coal, rate and regularity of duty required of boiler, condition of boiler, etc.—that record tests under the most favorable conditions are not fair comparisons. Experience, however, shows that from 10 to 13 pounds, and, in some specially favorable cases, a little over 13 pounds of water from and at  $212^{\circ}$  F.

per pound of combustible of good "screenings" or slack can be realized.

In comparisons with hand-firing we find a much greater saving shown in every-day work than is shown from record tests, because hand-firing on tests is usually by experts, or those who, by skill and extra care, realize from 10 to 25 per cent. better results than are obtained in regular work. Our experience, where we have displaced good hand-fired furnaces, shows savings of 20 per cent. or more in every instance, and in some cases has reached as high as 45 per cent., and in a few cases, where anthracite or expensive bituminous lump was used, the economy has reached 50 to 75 per cent. of former cost.\* To the advantage derived from such notable economy should be added those which are derived from its smokelessness, capacity, durability and general satisfactory service. It will meet sudden demands for increased steam with admirable promptness, because its unequaled coking capacity keeps the heating surface of boiler cleaner, and the fire can be "rushed" without opening the furnace or otherwise admitting cold or unnecessary excess of air, and without smoke.

[*To be concluded.*]

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## GEOGRAPHY OF PRECIOUS STONES.\*

BY GEORGE F. KUNZ.

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In speaking this evening on the geographical relations of precious stones, we may consider the subject in several aspects. Among these will be the geography of precious stones, with a brief description of some of the most famous gem regions; the influence of precious stones, both the search for them and the trade in them, on geographical exploration and discovery; the economic results of gem mining and gem traffic in the opening and settlement of regions otherwise remote, and the building up of cities and towns whose industries are the mining and the working of precious stones.

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\*A lecture delivered before the Franklin Institute, April 9, 1897. Copyrighted by George F. Kunz, 1897.

The geographical relations of precious stones are connected closely with the general topic of the history of commerce. I shall arrange the topics of this lecture, therefore, chiefly in their historical order, beginning with the earliest indications of commerce in gems, and passing down through classical and mediæval times to the conditions that we find to-day.

(1) Ancient and prehistoric time; in which all that we know is derived from the occurrence and use of precious stones in localities remote from their natural sources, or from very ancient traditions.

(2) Classical and mediæval time; embracing particularly the period of the Roman Empire and the centuries that follow, down to a recent date. Here our guides are literature, history proper, and the objects themselves in the great authentic collections of Europe.

(3) The modern world, with its immense developments of commercial, scientific and industrial progress, leading to new methods and new conditions in the procuring, working and transportation of precious stones and gems.

Beginning with a period before the existence of definite historical records, our first indications of the use of precious stones are found in Egypt and Assyria—in the latter at a period well established at about 4000 B. C.

A brief note on the forms into which gems have been cut in the various times may not be out of place here.

Precious stones in their natural state display but few of the beautiful qualities that we are wont to associate with them. These "crystallized flowers," as I have often heard our own Henry Ward Beecher call them, are frequently water-worn pebbles, roughened by attrition during years of wandering in the beds of streams and rivers; or, when found intact in their rocky homes, are often obscured by flaws and intruding matter which hide their beauty.

The earliest known gems were used as seals, either cylindrical, conoid, hemispherical or scarabæoid in form. The cylinder is believed to have been suggested by the joint of the bamboo, or the central whorl of a conch shell from which they

were first made. The conoid was a gradual evolution from the cone, then the hemispherical; then the scarabæoid, from the Egyptian scarabeus, or beetle, the symbol of immortality; then engraved gems. All of these seal gems were drilled; and about the beginning of our era, ring-forms, with the seal or subject on it, were made out of one piece of stone.

Such high artistic ideals as are portrayed on the gems from the sixth century B. C. to the fourth century A. D. have never been rivalled in any period of history.

Until the fourteenth century, all gems were either cut *en cabochon*, that is convex on one side like a carbuncle, or in the form of beads drilled from both sides in so rude a manner that the two perforations met very imperfectly. Then we have also the beads and faceted bead jewels of the East, brought into Europe by early commerce and by the movement of the Crusades, and the polished octahedral diamonds of the fifteenth century. Some of the finest gems in the crowns of Austria, Germany and Russia are sapphires and emeralds, that have been pierced partly or entirely, having served as pendants or as beads in Oriental necklaces centuries before. Rarely, if ever, have these ancient gems the perfection or beauty of color such as are demanded by the modern gem lovers. Finally, in the sixteenth and seventeenth centuries, we meet the faceted brilliant-cut stone, before whose clear light the superstitions of the centuries seem to fade away.

For a long time, it was supposed that the emeralds found in ancient Persian and Egyptian tombs and in the *débris* of the Alexandrian coast had come from the Ural Mountains—the great Russian locality of Takowaja,—but recent microscopical investigation by Schneider, of Dresden, has shown that they are from Jebel Zabarah, in Upper Egypt, where M. Caillaud, in 1830, discovered and reopened the ancient mines abandoned and forgotten for twenty centuries. These Zabarah emeralds were thus traded to the Orient, with garnets and turquoises from the Peninsula of Sinai, in return for the lapis lazuli of Media; and all the ancient lapis lazuli was from this source. It then was carved into the various forms of Osirids, scarabei, hawks and other objects so familiar in Egyptian art,

some found by De Morgan, in the tombs of the twelfth dynasty, 2400 B. C.; and all the emeralds used by the Tyrians, Etruscans and Romans were evidently Egyptian.

In the twenty-seventh and twenty-eighth chapters of the book of Ezekiel, we have a most vivid and detailed description of the world-wide commercial intercourse of ancient Tyre; and it is interesting to note how prominently precious stones are mentioned in this account. The Phœnicians were unquestionably the great receivers and distributors of these valuable objects from a very early day through many centuries.

Another, and one of the earliest and most interesting of the lines of prehistoric trade, is that of the amber commerce, from the Baltic to the Mediterranean, across Central Europe, and down the Rhone Valley to Marseilles, the ancient Greek Massilia. The amber, found in the Kertsch tombs in Southern Russia, Helm and Conwentz identify as of Baltic origin. It belongs to about the same age as that found in the Tyrian tombs, that is, 500 B. C. to 300 A. D. The myths, traditions and fancies that gathered about this singular and beautiful substance, its strange occurrence washed up by the waves on the shore of the Baltic, and its remarkable electrical properties, all combined to render it from very early times an object of mysterious interest and value, and to endow it with especial powers of supposed importance to health, safety and fortune. But amber is not out of, or given up by, the sea itself, or the tears of sorrowing seabirds, as stated by the poet, but is washed out of the tertiary coast deposits and sea-bottom, disturbed by the sea; and at present is not only dredged for by hand and steam dredges, but actually extensively mined from the same tertiary deposits miles inland.

Many of the most precious stones, however, such as the ruby and sapphire, have from the earliest ages been brought from the East Indies; and it is interesting to trace some of the stages in the history of trade with those rich regions of the earth. The first routes of commerce from the far East seem to have been two—one by the Persian Gulf and the Euphrates to Babylonia and Assyria, and thence by caravan through Damascus to Tyre and Sidon; the other by the

Red Sea and Suez to Egypt. Sir George Birdwood furnishes positive evidence that the Phœnicians visited India 2200 B. C.

The great early civilizations of Phœnicia, Mesopotamia and the Nile Valley, doubtless, thus became familiar with the gem treasures of Eastern Asia. Then came the opening of the Mediterranean, with first "the great Sidon," and later Tyre, as the starting points of commerce, exploration and colonial settlement among the islands and on the shores of what, to the Asiatic peoples, was the great western sea. As the Greek islands and their colonies developed, however, the Phœnicians confined themselves more to Africa and Spain. Gades, Tartessus and Carthage were their great colonies and trading ports, and their adventurous sailors passed on through the Straits of Gibraltar and northward to the British Isles for tin, and they very possibly obtained also the pearls of the Scotch rivers, as well as the Baltic amber; as centuries later, Suetonius tells us that Cæsar sent an expedition to obtain pearls for a buckler for the statue of Venus Genetrix. We even find indications of their having enslaved natives of the Spanish peninsula to work the mines of that region for gold, silver, topaz and other precious materials—even as the Spaniards of later ages dealt with the natives of the New World. It is to this date that we may attribute the Guarrazar treasure of the Spanish kings, now in the Cluny Museum in Paris.

The campaigns of Alexander had carried Greek influence and authority over all western Asia, reaching even to India itself, and had led to a widely increased intercourse. Alexander the Great, who lived to be only thirty-two years old, taught his merchants that their carrying capacity was increased one-fourth by using gold as a buying medium instead of silver; and precious stones were even a greater saving of camel power. In the bazaars of Alexandria, then as now, could be found the traders of India, Persia and Arabia bartering their treasured gems.

But Rome was destined to assume the leadership and to subject to herself all the resources and attainments of her early rivals. For the first time in history was there a great system of permanent and well-kept facilities for land travel and land

traffic. The great roads starting from the Forum reached out, in every direction, to the limits of the Empire. During the 500 years of Roman supremacy that followed the Phœnician sway, more gems were cut, mounted and worn than during any other early period; and at this time so abundant were engraved gems, that the outlines of the Roman Empire can be traced by the engraved gems alone, found in the tombs of its various dependencies. With the fall of the Empire, however, the Dark Ages came down like a cloud over Europe for 500 years; only among the Saracens and at Byzantium did any vestiges of the old civilizations remain; and in time the light of knowledge and progress was rekindled in Europe from these sources. The war and strife through the centuries of struggle between the Cross and the Crescent, beginning with the Crusades, ended only with the fall of the Eastern Empire.

To this period may probably be referred many of the finest jewels now found in the churches, collections and royal treasuries of Europe, especially the large peridots, some of them over an inch in diameter, such as those in the chapel of the Three Magi, at Cologne, which have long been believed to be emeralds, valued at \$15,000,000, but in reality peridots, worth only \$100,000. Their history and their source are unknown; but they are said to have been brought from Egypt centuries ago, whether as articles of commerce, as loot, or as mementoes of the Crusades, history fails to tell us.

The Crusades gave a mighty stimulus, by which Europe was awakened and brought into contact once more with the Orient. Venice and Genoa now became the carriers, first of pilgrims and war material, and then of a wider commerce, as intercourse and wealth increased. From this time and to this source may be traced many Oriental gems in Europe, and a new development of interest in them, as in many of the allied arts. Then followed the great period of mercantile prosperity for Venice and Genoa, which became the gem markets of the world, and founded stations and colonies around the eastern coasts of the Mediterranean, as the Phœnician cities had done so many centuries before. The Venetian fleet of 3,000 merchant ships brought the products of the East, and distributed



them over Europe, by way of the German cities of Augsburg and Nuremberg, where the great jewelers and silversmiths made world-famed products; and thence to interior Germany and the towns of the Hanseatic League; while the Rialto of Venice was the scene of many important gem sales.

With the advent of the "unspeakable Turk," Constantinople fell; and the wealth and treasure and learning of the Eastern Empire were scattered through Europe, to become the seeds of a revival of culture that broadened into the Renaissance. At the same time, the way to India and the far East was closed to the merchants and travellers of Europe; and hence new modes of access had to be sought by sea. With the voyages of Da Gama and Columbus, the newly-opened routes and the newly-discovered lands were claimed and appropriated by Spain and Portugal, while Venice and Genoa declined. Now began the wonderful period of Spanish and Portuguese development, colonizing and conquering in the Indies of the East and the West. In all this great activity, precious stones played a leading part. The search was evermore for

"The wealth of Ormus and of Ind,  
Or where the gorgeous East, with richest hand,  
Showers on her kings barbaric pearl and gold."

Portugal founded her colony of Goa, and from that time controlled the diamond trade of India. In the next century the diamond fields were discovered in Brazil, which also belonged to Portugal; but ere long, as so often in history, bigotry and oppression threw away the prizes which nature had given and enterprise had developed. The persecution of the Jews in Portugal led to a transfer of the diamond-cutting industry to Holland, and Amsterdam has since then been the diamond-cutting center of the world. In Spanish America the native races and semi-civilized empires of Mexico and Peru were overthrown amid treachery and blood, and a tide of plundered wealth began to set eastward to fill the coffers of Spain. It is one of the most marked instances in human history of rapid changes—social, economic, political and racial—resulting from the greed and the search for precious metals and gems.

After the conquest of Mexico, Cortez sent back to Spain a number of articles taken from the treasures of the unfortunate Montezuma, among which were some works in emeralds of quaint and charming beauty.

A somewhat similar account might be given of the Spanish interest in the pearls found in the possession of the natives of the New World. They attracted the attention of Columbus himself, and aroused in his mind great anticipations of the wealth of the region in these precious objects.

We are not dependent, however, on the Spanish chronicles alone for our knowledge of pearls in the New World. The prehistoric races of America made great use of pearls, and possessed them in enormous quantities, some from the true pearl oysters of the Pacific Coast and Panama. But De Soto's pearls were undoubtedly from the fresh-water shells (Unios) that abound in such profusion in the streams of the Mississippi Valley, and are even now yielding beautiful and valuable pearls at various points, though rapidly threatened with extermination by reckless seekers. The finding of thousands of fresh-water pearls in a single mound in the Miami Valley by Prof. F. W. Putnam and Mr. Warren K. Moorehead, the latter find now in the Field Columbian Museum, gives one a faint idea of the great abundance of this regal treasure of the waters.

Having thus followed briefly the history of the principal routes by which the precious stones of the Orient were brought to Europe and distributed among the Western nations, it is worth while to turn to some of the present and probable future aspects of the same subject. One curious fact which meets us here is, that under new conditions the gem traffic from the far East to Europe is beginning to return to the earliest courses—first, by the Suez Canal and the Red Sea; and second, by railroad routes now proposed from the eastern end of the Mediterranean *via* Damascus to Persia, and thence to India. We will now turn to some of the localities of precious stones.

Originally, and for many centuries, the only source of diamonds was India, where they occur in river gravels in several districts of the central and southern part. The chief of

these was the region near Golconda, in the valley of the Kistna River. The phrase, "diamonds of Golconda," refers not to the actual mines, but to the town to which they were taken for sale. It was the great diamond market, the capital of the district, the Kimberley, as it were, of the day, but is now little more than an abandoned fort, the Indian mines being largely worked out.

In 1734, diamonds were found in Brazil; and for 120 years large quantities came from this source, chiefly from the province of Minas Geraes, near Diamantina. They occur much as in India, in river gravels and surface deposits, and in a conglomerate of quartz pebbles, called *cascalho*, derived from the consolidation of older gravels. After various attempts to work the beds profitably, by the Government and individuals, the firm of Hope & Co., Amsterdam bankers, undertook the whole management, assuming the national debt of Brazil and receiving the entire output at the rate of \$9 per carat. This was about a century ago, and it resulted very successfully, and was the main cause of making Amsterdam the diamond market of the world. The persecution of the Jews in Portugal also led many of them to Holland who were diamond cutters, and this industry centered at Amsterdam, and gave it great commercial importance. Of late, Antwerp, London and Paris are overtaking it in this industry, Antwerp cutting one-quarter of the world's yield to-day.

Within the last thirty years the Brazilian mines have declined, and now furnish less than 5 per cent. of the world's supply (\$150,000 annually). Future introduction of improved methods and modern machinery, instead of the rude slave labor before employed, may render these mines again important; but at present they are overshadowed and undersold by the great African diamond yield.

The African discoveries, which have revolutionized the diamond trade of the world in a few years, began in 1866, and have had several distinct stages of development. The first diamonds found occurred, like those of India and Brazil, in river gravels, chiefly along the valley of the Vaal River, from Potchefstroom to the Orange River, and somewhat on that

stream. These, known as the "river diggings," are now of but limited importance.

In 1871 were discovered the "dry diggings," in Griqualand West, between the Vaal and the Orange Free State. These consist of several small areas, only a few hundred yards across, grouped within an area of a few square miles, the erosion of which had supplied the "river diggings." But here the diamonds occur in place, in earthy beds of decomposed volcanic rock; the upper portion is soft and yellowish, known as the "yellow ground," but at some depth it becomes harder and changes to a blue-gray color—the "blue ground," "blue stuff" or "blue." These are all altered conditions of the hard igneous rock peridotite, which is found unchanged at a depth of several hundred feet, containing diamonds in equal abundance. At the present depth of 1,200 feet, diamonds are as plenty as ever.

The commercial and industrial development of this region is simply marvelous. The city of Kimberley, with 55,000 inhabitants, and all modern appliances, has sprung up in a few years in the former desert; and the whole region is alive with modern activities. At first, the mines were worked as a host of separate small claims; but these were gradually united in a few large companies, and these, in 1889, were combined into the one immense corporation, known as the De Beers Consolidated Mining Company, which absolutely controls the diamond market of the world. Its capital is \$19,000,000, and its market value in dollars \$90,000,000. This gigantic scheme was planned and carried out principally by the genius and daring of one man, Mr. Cecil Rhodes, who became its chief director, ably seconded by his lieutenant, Mr. Gardner F. Williams, of California. Mr. Rhodes came to Cape Colony a lad, without wealth or influence; but in the diamond fields he rapidly developed both, and finally became the controlling head of the mining interest, then rose to prominence in the politics of Cape Colony, and became the organizer and head of the British South African Company. His great energy and ability, his prominence in recent aspects of South African politics, and his well-known ambitions regarding the extension and

unification of British interests and influence in that continent, all render him a conspicuous figure at the present time; but in justice to him let me say here that he is a creator, not a wrecker. When he prospered, everyone prospered.

The African mines have produced altogether about \$350,000,000 worth of diamonds, which, when cut, are worth \$700,000,000. This exceeds two-fold the value of all the diamonds previously known in the world. The Consolidated Company, which controls the whole of the district, limits the output, so as not to lower the price; and thus far all that have been produced have been taken up by the world. The trade is conducted by some 8,000 jewelers, carrying in stock about \$350,000,000 worth, which is about one-third of the whole amount of diamonds known. Fully 30,000 people are employed in cutting and selling diamonds, and 10,000 in working the African mines.

Next after diamonds in actual value come rubies and sapphires, which are the red and blue varieties, respectively, of the mineral corundum. These have long been brought from the far East; and it is only of late years that some of these localities have been accessible to Europeans. The true rubies have come chiefly from Burma, Siam and Ceylon, and it is remarkable that two of these regions, as well as the African diamond fields, are now under the control of Great Britain, and the Siam ruby fields are really in English hands. England well protects the sources of gold and precious stones. The famous ruby mines of Burma were an incentive for England to conquer the Burmese kingdom in 1888. Two wars, costing \$15,000,000, and the deposing of King Thebaw, who did not own the mythical dishes of rubies that were so famous, brought the mines into England's hands. The white-haired financiers who were clubbed from the offices of the Burma Ruby Mining Company, in their eagerness to obtain the stock which was subscribed for three times over, did not lose so much: it was then held at 300, now at 20, and has never paid a dividend. The much-prized pigeon's-blood rubies of Burma to-day command almost prohibitive figures in every land, are almost impossible to obtain, and they generally are old gems

sold by former owners. In Burma the climate is the greatest enemy of the European. Of fifty English officers who visited the mines, forty-eight had the local fever; the other two had had it before.

In Siam the gem-producing district lies in the interior, not very far from Bangkok. It produces many good rubies and sapphires; the rubies are generally darker in tone than the Burmese. The mines are worked by various persons and companies holding concessions from the Government. The gems are found in a layer of soft yellowish sand, at a depth of from a few inches to 20 feet. The methods of working are of the most primitive Oriental kind.

Ratnapura, the city of rubies, at the foot of Adam's Peak, Ceylon, at an altitude of 1,000 feet, is a great mining center. The most primitive mining has been carried on for ages past in that vicinity.

But the hopes entertained as to both Burma and Ceylon have hitherto been disappointed, nor does there appear any chance of future success, unless with improved methods of machine working. One who has been active in this gem-mining enterprise says: "What we want is an honest machine, one that will not only obtain for us the gemmiferous stuff, but that will securely guard it from the pickers and stealers until it can be raised to the surface and treated under close European supervision."

As a result of the work undertaken by European mechanical agency in Ceylon, the bazaars of Colombo were fuller than had ever been known before of gems of various kinds; yet only a few of these had passed through the hands of the companies working the mine. Thus, Kandy did not revolutionize into a South African regulated mining district.

*[To be concluded.]*

## A PHOTOGRAPHIC IMPACT TESTING MACHINE FOR MEASURING THE VARYING INTENSITY OF AN IMPULSIVE FORCE.

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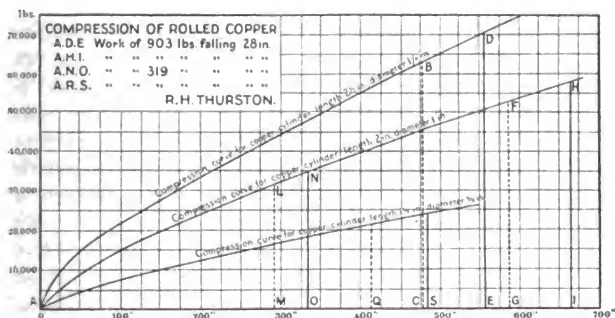
BY B. W. DUNN,  
Lieut. Ordnance Department, U. S. Army.

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### DISCUSSION.

R. H. THURSTON:—I have been much interested in this paper, not simply as relating to a somewhat novel phase of a subject which has been little discussed or worked up, but because many regard it—as, indeed, I do myself—as one likely to find valuable outcome in the art of determining the characteristics of the materials of construction. The wonderful success of Dr. Crehore and his coadjutors in the measurement of minute spaces traversed, and of variations of high velocities, has led us all to accept without prejudice any proposition looking to further development of similar methods or principles in any directions; and this is one of the evidently open fields for such further applications. The need of such processes of exact measurement was strongly brought to my own mind some years ago, when a controversy over the relative merits of heavy drop-hammers, and a dispute over a contract relating to them, was brought to me for settlement, if possible, by exact scientific methods of test of their efficiency. The attempt was then made to ascertain the work done, and to compare it with the power demanded, by crushing copper cylinders under the hammers and then comparing the effects with similar distortions produced in a compression-testing machine of the usual kind, measuring the weights required to produce measured quantities of distortion of crushing. While the work was useful in settling the question at issue, it brought very forcibly to mind the problem of securing a reliable measure of inertia effects and of their influence in modification of the results of the comparison between the static effects and the dynamic expenditures of work. The results of the tests thus made will be found described in Vol. III of my

"Materials of Engineering," Sec. 172, p. 281, with a plate presenting the curves derived. This plate is here reproduced with its scale reduced; but it is easily read and demands no remark in explanation. It was then stated in its accompanying text that "the effect of impact on the tough metals having no definite limit of elasticity is modified by the velocity of the striking mass, and by the inertia of the piece attacked, to an extent as yet not fully determined." It was concluded that the work of deformation increased, with soft and inelastic materials, with increasing velocity of striking. The contrary seemed to be the fact with, for example, irons and steels, in cases in which a definite elastic limit existed. In the figure,



the areas are obviously the measures of work done, and those cut off by full-line ordinates and by dotted lines, respectively, measure the work of the most and of the least efficient drop-hammers employed. The curves are apparently cubic parabolas.

The problem, of which the solution is here sought, is evidently, in fact, that of reducing inertia effects to quantities which, under the circumstances of the case in hand, may be neglected. Modern science and its methods of exact measurement are now supplying us with the means of solution, and the apparatus under discussion is an admirable illustration of such methods.

The paper before us gives a clue, at least, if not a com-



plete solution, of the problem, and permits comparison with far greater accuracy than ever before, I think perhaps with an accuracy which may be accepted as sensibly and almost physically perfect; and one of its most interesting results, seen in the figure comparing dynamic and static resistances (*Fig. 11*), is the proof that there exists a measurable difference between the deductions from the static and those from the dynamic system of test; while, nevertheless, this difference is not very important from the point of view of the designing engineer working any ordinary forms of structure or machinery.

The descriptions of the principles and methods described by the author of the paper are admirably rendered, and concisely and precisely exhibit the form of the problem and the means available for its solution. We have found in working within the steam cylinder of a steam engine, in the laboratories of the Sibley College, where no mechanism could be employed for such purposes, that the photographic film and a pencil of light could be made to trace variations of temperature most beautifully. The late Professor Mayer found the tuning fork a most satisfactory time-measuring instrument at high velocities and for minute intervals, and used it very extensively. The elements of the apparatus here employed have been well tested and may be relied upon, undoubtedly, in the new combination here illustrated. Lieutenant Dunn's method of measurement and scale making is extremely beautiful. The delicacy of the time-measurement system is something marvelous. In the distance-measurement, the apparatus has a theoretical perfection only modified, so far as I can see, by the inertia of the one material and inertia-laden element in the train—the mirror. It will be interesting to ascertain just how much error is introduced by this one moving solid body. If this error may be neglected, the system would seem to be practically perfect. The experiments of Mr. Hotchkiss, in the Department of Physics at Cornell University, in the use of an apparatus for the tracing, automatically and autographically, of the curves of fluctuation of the alternating electric current, indicate that, with a minute mirror, such as is easily made by the expert, a period of vibration, measured in thousandths of a

second, may be obtained, and the curves traced with practical exactness. With sufficient care in the production and attachment of a practically inertialess mirror, equivalent exactness of measurement should here be secured. For refined, and particularly for laboratory work, in the testing of the resistance of substances to impact compression, it would seem that this system should find practically useful application. The demand for more and more exact methods of experimental work in applied science and in engineering is constant, and is continually more and more imperative. Scientific research, in both pure and applied science, should here find valuable aid.

PROF. J. B. JOHNSON [St. Louis, Mo.]:—I have been much interested in reading Lieut. Dunn's paper on "Photographic Impact Testing Machines," and while I do not feel that I can add anything to the discussion, I will venture to call attention to the principal source of error in computing the impulsive force, or force of impact, from any such test. This source of error lies in the want of absolute rigidity of the base or anvil on which the specimen rests. If the specimen deforms largely under the blow, as compared to the movement of the base, then the error is small. But if the specimen does not thus deform or flow largely, as when it is subjected only to an elastic deformation from which it fully or almost wholly recovers after the blow, then the movement of ever so firm and rigid a base is likely to be large as compared to the (temporary) deformation of the specimen, in which case the computed force of impact, by this or any similar method, would be much greater than the actual force exerted. That is to say, this or any other method of computing the force of impact must rest upon the assumption that all (or some definite portion of) the energy of the falling weight passes into the specimen and spends itself in deforming it, either temporarily, or permanently, or both. This is the great unknown, and unknowable, function of the problem. Safety lies only in making the deformation of each and every blow very large as compared to the possible movement of the base under the blow. The failure to perceive this necessity is the fatal pitfall into which most experimenters with impact machines have fallen.

If the experiments made with Lieutenant Dunn's very ingenious machine be limited to some very malleable metal like copper, and to sizes and forces of blows such as to result in large deformations for each blow, and if the specimens be made to rest on very massive and rigid supports, as large blocks of steel, for instance, then the computed impulsive forces would be but slightly in excess of the actual forces which operated to produce such deformations.

For general purposes, however, in studying the resistance of brittle materials, like cast iron, for instance, to shocks or blows, this machine can have no important place. For such purposes a machine must be used such as will break the specimen at the first blow, and then indicate how much energy is left in the falling body (pendulum) after the specimen breaks. This, subtracted from the total energy in the moving body at the instant of impact, gives the energy required to break the specimen, but it gives no indication of the maximum impulsive force.

Such a machine has been designed, and is now in successful use by Mr. S. B. Russell, M. Am. Soc. C. E., of the water-works department of the city of St. Louis. For some purposes, however, as in gunnery, it seems necessary to find a measure of the maximum impulsive force, and as this cannot be assumed to be the same as is required to produce a like deformation, statically, then some such machine as that designed by Lieutenant Dunn is necessary. He seems to have solved this problem very successfully, and deserves, and I trust will receive, the thanks of the engineering profession. It is the first successful effort of the kind which has come to the writer's attention.

MR. GEORGE GIBBS:—From the hasty examination I have been able to give to Lieutenant Dunn's article, I should say that the author had developed the beginnings of what may prove an exceedingly valuable instrument of research to the physicist and engineer.

The engineering profession will certainly look forward with great interest to the development of a practical machine on these lines, and even if it is not possible to develop an instru-

ment which may be used in every-day commercial testing work, the results of the investigations with a laboratory machine would hardly fail to be of the greatest value to the profession.

The inadequacy of all the existing testing methods to give us knowledge of the effect of impact, has been apparent to all engineers having to deal with the testing of materials. In railway engineering, especially where the rolling stock and structures are subjected to the effect of impacts and rapidly alternating stresses, the lack of adequate means for the scientific investigation of a new material has been severely felt, and for this reason the introduction of new grades of material, or changes of proportions of structures, has been undertaken with the greatest caution. It will be seen that a more intimate knowledge of the maximum intensity of the stress developed by the blow might permit the quality of the material to be modified, with great advantage to the life of the structure.

I shall look forward with great interest to the development of Lieutenant Dunn's very beautiful machine, and only regret that I have not the opportunity to give the subject more careful consideration at this time.

I would suggest that Mr. Bond, of the Pratt & Whitney Company, would possibly be able to undertake the development of Lieutenant Dunn's machine, and if so, I know of no one more competent to produce the required results in accuracy of workmanship and refinement of design.

PROF. I. P. CHURCH [Ithaca, N. Y.]:—Being somewhat belated in this matter, the writer has been unable to make more than a hasty perusal of Lieutenant Dunn's description of his impact machine and methods pursued therewith, but is much impressed with the wonderful precision and delicacy attained in the subdivision of time and with the care and pains taken in the reduction and interpretation of results as traced in the autographic records.

As regards service to the civil engineer in the testing of materials, it would seem that the compression of a small cylinder of metal in the impact testing machine under consideration would be a useful and interesting addition to the pro-

cesses of a testing laboratory, but, at the same time, of quite limited scope. The use of the proposed brief relation

$$R = \frac{A M V}{T}$$

for the maximum pressure bringing into play, as it does, the total time of shortening and dispensing with the drawing of the "impact curve," implies that the experimenter, in selecting a proper value for the coefficient  $A$ , must make use of some acquaintance with the general characteristics of that curve, for the metal under test, as obtained previously with Lieutenant Dunn's complete apparatus. Hence, in dealing with a metal, or brand of metal, for the first time, the more elaborate apparatus would be needed, after all, and the impact curve found and interpreted, before the maximum pressure could be found.

It would seem as if a photographic device of the kind used by Lieutenant Dunn would be found more accurate in the production of autographic stress-strain diagrams below the elastic limit, in the use of the ordinary static testing machine, than those heretofore employed for this purpose (such as Professor Gray's, for example), where the magnifying of the change of length of the specimen is brought about by mechanical means. In a photographic apparatus, the Bauschinger rollers and mirrors could be used, each throwing its own beam of light on a cylinder, while the rotation of this cylinder, carrying the sensitive film or paper, could be made to keep pace with the travel of the poise; the motion of the spot of light on the paper being parallel to the axis of the cylinder.

As regards the phrase "impulsive force," in the first part of Lieutenant Dunn's paper, it may be well to call attention to the fact that recent writers on applied mechanics do not make use of the term, unless in disapproval, and treat the duration of contact of two bodies during impact as composed of an infinite number of infinitesimal elements of time, exactly as longer periods of time in other motions are considered; so that it seems a little out of place to speak of the "usual" classification of forces into "impulsive," etc.

It seems to the writer that in some of Lieutenant Dunn's

diagrams the expression "velocities after impact" would better be replaced by "velocities after the instant of first contact." As to the foot-note on p. 341, the algebraic work there given might, perhaps, have been dispensed with, and the simple statement made that the ellipse (or circle, if the scale be properly selected) is the well-known "distance-velocity" curve for a harmonic motion, where the retarding force is proportional to the displacement, or distance from the midpoint of the amplitude; and that the parabola performs the same office for the case of a constant retarding force.

The application of Lieutenant Dunn's apparatus to the ordinary impact testing machine would doubtless lead to interesting comparisons between results obtained with different sizes of "anvil" and different designs of support of the latter; in transverse tests of cast-iron bars, for instance.

MR. JAMES CHRISTIE:—The ingenious device of Lieutenant Dunn, for measuring and recording the effect of an impulsive force, is an example of a highly sensitive and delicate mechanism for registering those rapid and minute deformations in material, that could not be obtained with any degree of accuracy by less precise methods.

The extreme tenderness of the apparatus might seem to imply that its place is in a philosophical laboratory, where results determined from carefully prepared specimens are required with the highest possible precision. There would seem to be no reason, however, why the instrument in a modified form could not be very useful in the laboratory of the shops as a valuable adjunct for studying the physical properties of materials. We have very little data on the effects of impactive forces and of vibrations, for the reason that a correct record of such tests has been difficult to obtain, notwithstanding the acknowledged utility of tests of this kind. As such experiments have usually been of a crude and indeterminate character, owing to the imperfection of the recording mechanism, we are still lacking in experimental knowledge of the effect of dynamic action.

Although our literature is replete with the records of tests derived from static forces, we are still asking what are the

stress intensities and deflections, or other deformations, resulting from the impact of moving bodies of known mass and velocity? How are the strains localized or distributed throughout the body impinged upon? What are the extent and character of the stresses resulting from vibration? When do vibrations acquire such intensity as sensibly to constitute fatigue of strength or elasticity? Or is there such a thing as fatigue of elasticity as suggested by Lord Kelvin many years ago? The solution of these and similar problems awaits the advent of a suitable testing machine, whose records can inspire confidence.

This is a fruitful field of work for the aspiring youth of the technical schools, when searching for fresh fields and pastures new, and one from which rich harvests of knowledge may be garnered.

LIEUTENANT DUNN:—The writer is under many obligations to the Franklin Institute for its reception and treatment of this paper, and to the participants in the above discussion for their valuable criticisms and suggestions.

In all departments of scientific research we observe a constant addition of new and a continued subdivision of old specialties. The consciousness that his work is in a virgin field is a wonderful stimulus not entirely free from danger to the investigator. There is a critical stage in the rise of enthusiasm, after which a judgment, previously sound, becomes clouded and the specialty develops into an emancipated hobby.

During the development and use of the apparatus described, the writer had in view only the military interests in impact. The possible utility of his work to other branches of the engineering profession was an after-thought. A discussion was sought for two reasons:

- (1) To determine, through the crystallized opinions of abler minds, whether the writer had become the victim of his own enthusiasm.

- (2) Because the engineering profession must acquire an active interest if the great amount of necessary laboratory work is to be accomplished.

In addition to the above comments, many encouraging letters have been received from eminent engineers who, from lack of time, have not been able to join the published discussion.

Granting the creation of an active interest in the profession, it will not be difficult to arrange for a continuation of the work. The apparatus is not a costly one, and the possible results affect so many important interests, that it would be eminently proper for the general Government to bear the expense of a commission of experts, appointed to continue the investigation. The combined influence of a few eminent engineers could readily secure the necessary appropriation from the Congress.

Some of the points raised in the discussion require further notice. Through space limitation, the foundation for anvil and other important details were omitted from the published paper. Any appreciable deformation of the surface on which the specimen rests would, of course, vitiate the test. For the experiments described, a steel anvil, 10 inches in diameter and 12 inches long, was embedded in a mass of concrete, 4 by 2 feet, by 6 feet in depth, filling a hole of corresponding dimensions in dry earth.

The writer does not agree to Professor Johnson's limitation of the apparatus to plastic materials. The stresses developed by the blow can be distributed over a comparatively large anvil surface, and, with a degree of hardness in a massive anvil superior to that of the specimen, all danger of the "fatal pitfall" will be avoided. A block of Harveyized nickel-steel should not be affected by the stresses required to deform and rupture cast iron specimens. It is reassuring, also, to know that the extremely sensitive little mirror can be made to tell us whether any appreciable deflection of the upper surface of anvil is produced.

The reasons calling for an increase in our knowledge of the action of structural materials under rapidly applied stresses are stated very forcibly by Mr. Gibbs.



Prof. Church will see, by referring to the last two paragraphs, page 41, that it is not proposed to use the formula

$$R = \frac{A M V}{T}$$

in testing a new material. The construction of tables to give values of  $A$ , as a function of  $T$ , and possibly of  $V$ , for structural materials, is the laboratory work referred to as necessary. Even after this is done, it may be preferred, in important tests, to use the complete impact curve, which could be obtained and interpreted in less than an hour.

It is thought that a perfected system of revolving mirrors may throw some light on the profound questions propounded by Mr. Christie.

In introducing his interesting comments, Professor Thurston refers to the excellent work of Dr. Crehore and his coadjutors, and then to the writer's work as a "further development of similar methods," etc. This impression flows naturally from the priority of date of Dr. Crehore's published reports, but it is incorrect. The writer's apparatus was designed, constructed and used in 1891, about three years previous to the publication of Dr. Crehore's reports. Nothing was published concerning it, because the work was official, and it depended entirely on the Secretary of War to say when the publication should take place. Additional work was done in 1894, and the first publication\* appeared in 1896.

It seems unsafe to predict, at this time, just where reliable impact data will be of practical value. It is quite safe to assume that such data will find a warm welcome in all branches of the engineering profession.

The relation of the mass of specimen to the difference between static and impact curves is important, and remains to be elucidated.

The copper specimen showed a higher dynamic resistance, because its molecules possess mass, and the conditions required a motion to be produced in them in a very short time. No matter how small the mass, the moving power must approach infinity as the time approaches zero. For a constant

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\* Ordnance Construction Note, No. 71.

difference in time of application of static and dynamic loads, the difference in corresponding resistances should increase with the mass.

The details of the apparatus described are susceptible of great improvement. The writer is occupied at present with a new instrument to investigate a problem of military interest, where the desired data will be far more difficult to obtain. An attempt will be made to secure a great increase in delicacy and accuracy of recording mechanism, and any improvements of this nature that may result will be available for use in the impact testing apparatus.

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## Mining and Metallurgical Section.

*Stated Meeting, held Wednesday, November 10, 1897.*

MR. BENJAMIN SMITH LYMAN, President, in the chair.

### KRYOLITH—ITS MINING, PREPARATION AND UTILIZATION.

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BY WILLIAM C. HENDERSON.

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The mineral kryolith is the double fluoride of sodium and aluminium. Its composition is expressed by the formula,  $6\text{NaF}, \text{Al}_2\text{F}_6$ . It is made up, therefore, of sodium = 32.86 per cent., aluminium = 12.86 per cent., and fluorine = 54.28 per cent.; sometimes carrying sesquioxide of iron as an impurity. It crystallizes after the monoclinic system—occurs both in the crystalline and massive forms, usually in the latter. It is snow-white to smoky-dark in appearance; cleaves in three directions, showing rectangular cleavages; is brittle, with an uneven fracture; is translucent, and has a vitreous to greasy luster. It has a specific gravity of from 2.95 to 3.0, and a hardness of 2.5. It is fusible in the flame of a candle, its melting point being between  $900^\circ$  and  $1,000^\circ$  Celsius. It is soluble in sulphuric acid with the evolution of hydrofluoric acid. It is slightly soluble in water, Johnstrup giving this solubility as 1 part in 2730 at  $12^\circ$  C.

The earliest notice of this mineral was by Schumacher, in

1795, from a sample brought by a missionary from Greenland to Copenhagen. Here, from its resemblance to barite, it lay neglected until 1799, when Abildgaard, whose attention was attracted to it, undertook its examination, in the course of which hydrofluoric acid, hitherto known only in connection with fluorspar, presented itself, along with aluminium. A considerable residue remained unaccounted for, however, and the investigations were repeated by Klaproth, in 1800, who discovered the presence of sodium.

Its great fusibility, as well as its resemblance to snow, and still greater likeness, when wet, to ice, suggested to Abildgaard the name which he gave it—kryolith—from *κρύος*, frost, and *λίθος*, stone.

The mineral was later described by D'Andrada and Karsten.

In 1811, Giesecke, who was a member of the Danish Geological and Mineralogical Survey of Greenland, discovered in the colony of Frederikshaab, in southwest Greenland, at the place now known as Ivigtut, an immense deposit of kryolith. During the same year he shipped a considerable quantity of minerals, including kryolith, for Copenhagen; but as this was during the stormy period of the Napoleonic wars, the vessel never reached her destined port. She was captured by a French privateer, recaptured by an English frigate, and was finally taken into Leith, Scotland, where the cargo was condemned as worthless, and sold to Thomas Allan, an Edinburgh mineralogist, for £40.

The deposit of kryolith discovered by Giesecke, at Ivigtut, is the only one of commercial importance known at present, and no indications of its existence at any other locality in Greenland have been discovered. Comparatively small quantities have, however, been found at Miask, in the Ural Mountains, between Russia and Siberia, separated from the civilized world by 1,000 miles of desert. Also at the northeast base of St. Peter's dome, in the Pike's Peak region of Colorado, and lately it has been reported from the Yellowstone National Park, Wyoming.

The minerals usually associated with kryolith are quartz,

siderite (which occurs perfectly pure in beautiful crystals), galenite, sphalerite, pyrite, chalcopryrite and wolframite. These are irregularly scattered throughout the mass of kryolith in a manner most remarkable. They are, for the most part, easily separated during the operation of sorting, which takes place at the mines.

There are, besides, several minerals found only in connection with kryolith, some of which were, until recently, entirely unknown. Among these are: Pachnolite, thomsenolite (named after Thomsen, the originator of the kryolith industry), arksuktite, gearksuktite, ralstonite, prosopite, ivigtite (from Ivigtut) and hagemanite (named by Professor Silliman, after Hageman, who first analyzed it). These interesting impurities are readily separated from kryolith, in the process of manufacture, as they suffer no change under the chemical treatment by which the kryolith is decomposed. Eudialite also occurs in the Ivigtut region, this being the only locality—except one or two others—where it has been found.

Kryolith was at one time the chief source of aluminium, remaining so until superseded by bauxite. It is still used in the production of this metal, but not as a source of supply. Aluminium was first obtained from kryolith early in 1855, by Allan Dick, who fused the mineral with alternate layers of small pieces of sodium, in a magnesia-lined crucible.

The principal use for kryolith is found in the manufacture of soda and the by-products resulting therefrom. From no other known substance can soda be obtained with equal cheapness and abundance; and it is the only natural product, excepting salt, from which this commodity can be procured in quantities sufficient to supply the demands of commerce. The process by which soda is obtained from kryolith was devised by Prof. Julius Thomsen, of Copenhagen, in the year 1850. Still another use for kryolith exists in the production of kryolith glass, or hot-cast porcelain, a beautiful translucent substance, possessing great strength, first brought prominently into public notice by the Hot-Cast Porcelain Company, of Philadelphia, by whom it was made on a large scale, although the material had been in use in Bohemian and Silesian glass

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works for some years previous to the commencement of the manufacture in America.

Ivigut (an Eskimo word, meaning "a meadow") is located in latitude  $61^{\circ} 10'$  north, and longitude  $48^{\circ} 10'$  west, being a spot of land on the Arksuk Fiord, twenty miles from the coast line of southwest Greenland—a remote and gloomy region of the globe, inaccessible during the greater portion of the year, and barren of all commercial products, save kryolith.

The inhabitants of Ivigut are solely the officers and men who operate the mines, all of whom come from Copenhagen. With but one or two exceptions, there are no women at Ivigut. The settlement is in possession of a Lutheran church, and boasts among its social attractions, a bowling alley, a billiard parlor and a brewery. The food consumed by the people is almost exclusively supplied from Copenhagen, and consists chiefly of rye bread and salt meat, with fresh meat once or twice a week.

The nearest Eskimo settlement to Ivigut is at Isua,  $8\frac{1}{2}$  miles distant.

As though with a view to insure the speedy discovery of this unique and most remarkable mineral occurrence, nature signally marked the spot with a giant monolith of spotless kryolith, which, carved through countless ages by glacial action, stood, a towering monument upon the buried treasure beneath. It further revealed itself by a series of graceful undulations separated by green sward. Its resemblance to snow was, indeed, so great, that one can readily appreciate the Eskimo belief that it was such, though of a special kind that would not melt.

Remote from civilization as is the location of this isolated deposit, at no other point, in Greenland, at least, could it have been more accessible for removal, no portion of the mineral being at a greater distance than 150 feet from low-water line, and its general elevation not exceeding 10 feet from high water. Its greatest length extends in a direction parallel to the sea in a line running northeast and southwest, covering a distance of about 400 feet, 100 feet of which is washed by the sea. That portion nearest, and facing the sea, descends per-

pendicularly to an unknown depth; that farthest from the water sinks at an angle of about  $45^{\circ}$  from the sea.

The width in the opposite direction, that is, southeast to northwest, is about 150 feet.

The deposit of kryolith, at Ivigtut, is owned by the Danish Government. The mining of the mineral is conducted exclusively by a Copenhagen company, by virtue of a lease held by them from the Government. By the terms of this lease, the value of every fifth cubic fathom of kryolith, mined and shipped from Greenland, falls to the Danish Treasury of State, whether the cargo be lost on voyage from Greenland or not. These kryolith mines were opened by Daniel Schmidt, in the year 1858. The first cargo of commercial note was shipped from Ivigtut to Copenhagen, in 1857, on board the bark *Christian*; and the first shipment to the United States was made in 1864, being consigned to Philadelphia. In January, 1865, a contract was completed with Handels Selskabet, of Copenhagen (operators of the mines at Ivigtut), by which the Pennsylvania Salt Manufacturing Company, of Philadelphia, became possessed of the exclusive privilege to import the mineral, from this deposit, into the continents of North and South America.

That portion of the mine, which may more properly be termed the quarry, at present measures about 300 feet in length, 150 feet in width and 120 feet in depth. Three holes have been sunk still deeper into the mass, for the purpose of investigation. The deepest of these is now about 120 feet below the bottom level of the quarry, but even at this depth there are no indications that the lower boundary of the mineral has been approached.

During the summer season, which lasts from about April to November, about 140 men are employed in quarrying, mining, sorting and piling the kryolith. The drilling is done by hand, no steam drills being used, and the mineral is dislodged by blasting. It is carefully sorted into two grades, Nos. 1 and 2, of about 99 per cent. and 92 per cent., respectively, which are taken to the top of the mine in 2-ton cars, running on an incline railway operated by steam. The kryolith is carefully and accurately formed into piles of exactly 100 feet long,

20 feet wide and 4 feet high, containing 8,000 cubic feet, or about 37 cubic fathoms. The cubic fathom constitutes the unit used in estimating the quantity shipped, the more general practice of weighing not being adopted at Ivigtut. The weight of a cubic fathom of kryolith is 13·6 tons of 2,240 pounds. The greatest quantity of kryolith taken from the mines, in any one season, was that removed during the season just closed. It amounted to 13,000 tons, of which 10,500 tons were received at Philadelphia.

The best grade goes to Copenhagen; the second quality comes to Philadelphia.

The waste, including everything taken from the mines except the kryolith, is dumped into the sea, after a regular system, for the purpose of building wharves, and securing more reachable anchorage. This is extremely desirable, owing to the remarkably precipitous character of the coast. Just before winter sets in, a sluice is opened, and the mines are flooded with sea water. The object in this is to prevent them from becoming inoperative through an accumulation of ice and snow, which the whole of the summer's heat would not suffice to melt.

The force of men is then cut down to about seventy, whose efforts are chiefly confined to the quarrying of such of the kryolith as can be reached, allowing it to accumulate for removal the following summer.

Rails have been laid during the winter upon the ice in the quarry, and the whole operation carried on the same as in summer, except upon a much reduced scale. This, however, has not been found to be thoroughly practicable.

As soon as the general thaw takes place, steam pumps are put to work, the mines drained of water (an operation requiring about three weeks to perform), and work is again resumed in earnest.

The vessels employed in the kryolith trade are staunch sea-craft, built expressly for the purpose. The Philadelphia fleet musters, just now, eight barks, having an average burden of 800 tons; while three small vessels, with an average of 300 tons burden, comprise the Copenhagen fleet. These make

two trips to the mines a year, arriving at Ivigtut, on the first trip, about April 10th, and again, on their second one, July 10th. Owing to the lack of reciprocity, these vessels usually make their outward voyages in ballast.

In producing soda from kryolith, Thomsen's method is still employed. The process briefly is as follows:

The previously dried and pulverized kryolith is intimately mixed with an equal weight of powdered limestone, and the mixture calcined at an incipient red heat, during which there is formed calcium fluoride, aluminate of soda, carbonate of soda and sodium hydrate. The calcined residue, known as "kryolith ash," is then subjected to careful leaching, yielding an insoluble residue of calcium fluoride and a solution containing the soda salts. The insoluble fluoride of calcium is purified by washing and is ready for the market. The solution containing the soda salts is conveyed to agitators and agitated in contact with carbonic acid gas. During this operation the soda becomes united with the carbonic acid, to form sodium carbonate, still, however, remaining in solution. The alumina separates out as aluminium hydroxide, which, upon being purified by washing, is either converted into alum, or sold as alumina.

The solution containing the carbonate of soda is concentrated to about 36° Beaumé, and the salt allowed to crystallize out, thus finally becoming the sal soda of commerce.

If it be desired to make the bicarbonate, this last product is exposed to an atmosphere of carbonic acid gas, of which it absorbs another equivalent, and yields its water of crystallization.

In the manufacture of aluminium, kryolith is used in the fused bath as a solvent, into which is introduced pure alumina, to the extent of about 21 per cent. of the weight of the kryolith (this being a much greater amount than it has been found possible to introduce into any other available substance). By electrolysis, the alumina is decomposed into its component parts, the oxygen uniting with the carbon, furnished by the highly-heated carbon electrodes, to form carbon monoxide, which escapes and burns at the surface of the bath to form car-



bonic acid gas, the aluminium being deposited at the bottom of the furnace.

In the production of kryolith glass, or hot-cast porcelain, 4 parts of powdered kryolith are mixed with 10 parts of silica and 1 part oxide of zinc. The whole is then fused and manufactured into ware, much after the same manner as is ordinary glass; but is unlike the latter, not only in appearance, but also in possessing great toughness and hardness, so that a plate, for instance, stamped out of this material, may be thrown down quite violently, without fear of its breaking.\*

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## ELECTRICAL SECTION.

*Stated Meeting, November 17, 1897.*

MR. C. W. PIKE, President, in the chair.

### RAILWAY BONDING.

BY WALTER E. HARRINGTON.

Each manufacturer of rail bonds states his bond to be the best; the number of bonds now upon the market approximate closely about twenty different designs.

It is a difficult matter to determine which bond is the best adapted to your conditions. What may possibly answer under certain conditions will not answer under others. The majority of bonds are designed to make lateral contact with a hole in the web of the rail. This at once defines the necessity of good, clean, uniform surface in the hole, in order to insure good contact. While it may seem an easy matter to obtain good, clean, uniform surfaces, the facts are, that in the majority of instances, holes are not true and are full of ridges.

The writer has frequently removed bonds, where it seemed

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\*The author wishes to acknowledge his indebtedness to the gentlemen named below, for much of the information contained in this paper, and to thank them, also, for their kind aid in its preparation: Mr. Theodore Armstrong, President P. S. Mfg. Co.; Mr. Daniel Schmidt, who opened the mines at Ivigtut; Capt. Smith, of the kryolith bark *Calcium*; Capt. Anderson, of the kryolith bark *Serene*; Dr. J. V. Ingham, of Philadelphia; Mr. C. H. Ingraham, of Philadelphia; Mr. J. H. Lynch, of Philadelphia.

as if every precaution possible had been observed to make good contact, with barely more than 10 per cent. of contact. In some instances, the bonds could be readily pulled out of their holes.

Furthermore, rails will be either punched or drilled for bonds by the mill, and the holes will frequently become coated with rust before the rails are placed, resulting either in the necessity of using a file or reamer, making the holes larger than they should be. I do not wish to convey the impression that good contact cannot be made with bonds making connections through a hole in the web of the rail, as this can be done; but the frequent bad contacts upset one's confidence in them.

The use of the Edison-Brown amalgam, to improve the contacts of copper bonds, showed some very interesting results; used with the Crown bond, manufactured by the Washburn & Moen Manufacturing Company, the joint showed a decrease of 24 per cent. in resistance by amalgamating; whereas the Columbia bond, manufactured by the John A. Roebling's Sons Company, only showed a decrease of 5 per cent., showing conclusively that the forms of contact made by the Columbia bond is far superior to the Crown. This is substantiated by the data in attached table, which show that the Columbia bond has a resistance 53 per cent. of the Crown (neither amalgamated).

The troubles incident to making contact in a hole in the web of the rail led to the trial of the much-abused Bryan bond. This bond consists of a large number of parts, and is open to the objection that a bronze casting is used as part of the conductor. The bond, in brief, consists of two No. 0000 copper wires, clamped by bronze and iron castings, the bronze casting in contact with a corrugated copper washer, which is in contact with a freshly-made contact surface upon the face of the rail; the whole held together by a 1-inch bolt and nut, with a lock washer. This bond overcomes the radical objections inherent in the type such as the Crown, Columbia, depending upon their contact with the sides of a hole. The resistance of such a bond without the Edison-Brown alloy is very high. Compared with two Crown bonds non-amalgamated,

it shows a resistance 146 per cent. higher, but the amalgamation makes a remarkable difference; comparing it with the non-amalgamated Crown bond, makes a difference of just 42 per cent. in favor of the Bryan (when amalgamated); whereas compared with two Crown bonds, amalgamated, makes a lesser difference of 23 per cent. in favor of the Bryan bond, amalgamated, with a still further advantage of permanency.

The great objection to the Crown, Columbia, etc., type of bonds consists chiefly in the mechanical defects inherent in them. The vibration of the rail, with the play of the rail joint, results in a continual stress upon the small area of the contact, followed with the final loosening of the bond.

The writer has removed bonds of the above types which had been in service only a few years, and that had become loose, and the continual movement had worn the bond approximately  $\frac{1}{8}$ -inch smaller in diameter in places. The Bryan bond and those types which are flexible, particularly the Edison-Brown type, are free from such mechanical defects.

While it was not the purpose of the writer to make the tests herein outlined to demonstrate the virtues of the Edison-Brown, still the results were so pronounced that especial stress is laid upon them, particularly since practical experience has demonstrated their permanency.

It will be noticed that the plastic cork type of Edison-Brown bond gave the lowest resistance of any of the bonds tested.

#### Conclusions:

(1) The Edison-Brown plastic cork bond gives the best results.

(2) The Standard bond, under fish-plate, is excellent, but is difficult to place.

(3) The Bryan bond is the best round fish-plate type of bond, both electrically and mechanically, provided however, that the bond is thoroughly amalgamated with the Edison-Brown alloys.

(4) The Crown and Columbia types of bonds would not be so objectionable if they were stranded, and the strands protected from electrolysis.

(5) The Crown type of bond is rendered materially efficient by the use of the Edison-Brown alloys; while the Columbia type is only benefited slightly. In both instances the Columbia is the better bond.

(6) Iron-wire bonds are highly inefficient.

(7) Any method of testing wherein drop in potential is measured from the same contacts through which current flows to make measurements, lead to false readings, as the measurements include the drop in the contacts.

Kind of Bond.	Center to Center of Contacts	Length of Bond.	Size of Contact.	B. & S. Gauge.	Number of Wires in Bond.	Ohms.	Per Cent. Res. — A B
	Inch.	Inch.					
Joint only—no bond . .	36	—	—	—	—	'00071	—
Iron channel pin . . . .	45	48	$\frac{3}{8}$ " pin Plate $2\frac{3}{4}$ " d. 1" hole in it	0	1	'00049	69
Bryan—Iron wire . . .	36	39	$\frac{3}{8}$ " head Plate $2\frac{3}{4}$ " d. 1" hole in it	$\frac{1}{2}$ "	2	'000286	40
Crown . . . . .	30	36	$\frac{3}{8}$ " head	0000	1	'000247	34
Bryan—Iron wire, amal- gamated . . . . .	36	39	$\frac{3}{8}$ " head Plate $2\frac{3}{4}$ " d. 1" hole in it	$\frac{1}{2}$ "	2	'000224	31
Crown, amalgamated . .	30	36	$\frac{3}{8}$ " head	0000	1	'000185	26
Bryan—Copper wire . .	36	39	$\frac{3}{8}$ " head Plate $2\frac{3}{4}$ " d. 1" hole in it	0000	2	'000175	24
Columbia . . . . .	30	36	$\frac{3}{8}$ " head	0000	1	'000131	18
Columbia, amalgamated	30	36	$\frac{3}{8}$ " head	0000	1	'000126	17
Stranded crown . . . .	5	7	$\frac{3}{8}$ " head	0000	1	'0001	14
Plastic socket . . . . .	$3\frac{1}{2}$	—	—	—	—	'000093	13
Bryan—Copper wire, amalgamated . . . . .	36	39	$\frac{3}{8}$ " head Plate $2\frac{3}{4}$ " d. 1" hole in it	0000	2	'000071	9
Plastic cork . . . . .	9	—	Surface $1\frac{1}{4}$ " d	—	—	'00006	8
Solid rail—no joint . .	18	There	were	holes	in web	'000013	—

Tests made on Penna. Steel Co. 7-inch girder rail, No. 238.

A = Resistance of bond. B = Resistance of joint only.

11-22-'97.

ON THE DENSITIES OF NITROGEN, OXYGEN AND ARGON, AND ON THE COMPOSITION OF ATMOSPHERIC AIR.

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BY A. LEDUC.

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*Translated from Comptes Rendus de l'Académie, 1896, vol. cxxiii, page 805.*

BY CHIEF ENGINEER ISHERWOOD, U. S. Navy.

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As the discovery of argon has modified some numerical results concerning atomic weights, molecular volumes, and, chiefly, the density of nitrogen, which I have heretofore published, I have again been led to further experiment on some gases,\* particularly oxygen, the density of which according to my previous experiments, seemed to me to be a little too low, relatively to that of chemical nitrogen.

*Nitrogen.*—Lord Rayleigh, who had already determined the density of nitrogen prepared in different ways, has done me the honor of communicating in writing his experiments, the chief object of which was to ascertain whether the density of this gas were independent of the process of preparation. I propose to find, as exactly as possible, the density of nitrogen, prepared by the following processes that seem best adapted to furnish it in a state of purity:

(1) Decomposition of the nitrite of ammonium by heat. The gas obtained contains considerable quantities of the oxides of nitrogen and of ammoniacal gas; it is purified by a long column of copper, followed by oxide of copper raised to incandescence.

(2) Decomposition of the nitrate of ammonium by heat. The impure nitrogen protoxide thus obtained is treated as above.

(3) Decomposition of nitric oxide by incandescent copper.

(4) Decomposition of ammoniacal gas by incandescent oxide of copper; which oxide is followed by a column of

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\* Executed in the Physical Laboratory of the Sorbonne.

copper that has for its object the decomposition of the oxides of nitrogen produced by the preceding reactions.

In all cases, the nitrogen obtained traverses, before entering the weighing globe, a column of potassa, and another of pumice stone saturated with  $\text{H}_2\text{SO}_4$ , and a U-tube charged with phosphoric anhydride.

A vacuum is made in all parts of the apparatus, previous to the operations, in order to prevent the presence of argon.

The weights of nitrogen, at  $0^\circ$  and 76 cm. contained in the globe, are comprised between 2 gr. '8467 and 2 gr. '8474; their mean, 2 gr. '8470, corresponds, all corrections made, to the density 0.96717\* relatively to the density of air.

*Oxygen.*—I have previously found for the density of oxygen relatively to the density of air 1.10506. Although this number is the result of only a single series of experiments—electrolysis of a solution of potassa—I have accepted it without hesitation because it harmonizes with other results obtained up to the present time.

After the discovery of argon this number appeared to me to be a little too low, and I then prepared the oxygen by decomposing by heat the crystallized permanganate of potassa. Before entering the weighing globe, the gas passed over potassa, acidified pumice and sulphuric anhydride. The density was found to be near 1.10527.

I now prepared the oxygen by electrolysis, but instead of a short column of spongy platinum, I employed for eliminating the hydrogen a long column of oxide of copper at a dull red heat. Three very concordant experiments gave 1.10521.

Convinced by these latter experiments of the insufficiency of the spongy platinum in the preceding ones, I accept for the density of oxygen 1.10523.

*Argon.*—I have many times had occasion to remark that the close concordance of the numbers obtained by Lord Rayleigh and by myself for the density of atmospheric nitrogen, implied the constancy of the proportion of argon in the atmos-

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\* As I have remarked in previous publications, the last decimal may have an error of several units. Further, as the present number has much probability of being too great, it can, with prudence, be reduced to 0.9671.

phere. This point has recently been put beyond doubt by Mr. Schloesing, Jr.,\* who has found the proportion of argon in atmospheric nitrogen to be 0.0119.

Designate by  $d$ ,  $d'$  and  $x$ , the densities of chemical nitrogen, atmospheric nitrogen and argon.

$$\begin{aligned} \text{We have } (d' = 0.97203). \\ d' = 0.0119x + (1 - 0.0119)d. \\ \text{Whence results } x = 1.376. \end{aligned}$$

Or, relatively to hydrogen, 19.80, instead of 19.9, heretofore accepted.

*Résumé.*—It will be useful to fix these results by giving the weight of a liter of each of these gases at 0°, both under the pressure of a bayre ( $10^6$  C. G. S.) and under the normal pressure of the atmosphere at Paris, as follows:

Pressure.	Oxygen.	Nitrogen.	Argon.
1 Bayre . . . . .	1 gr. 4100	1 gr. 2338	1 gr. 755
1 Atmosphere . . . . .	1 gr. 4293	1 gr. 2507	1 gr. 780

I shall return hereafter to the atomic weights of nitrogen and oxygen.

*Composition of Atmospheric Air.*—I have a great many times determined the composition of dry atmospheric air deprived of carbonic acid, etc., and have found that it contained in mean  $\frac{2.32}{1000}$  of its weight of oxygen.

The consideration of the densities of oxygen and atmospheric nitrogen † leads to the number 232.08, which can be taken as identical with the preceding.

On the other hand, the  $\frac{7.68}{1000}$  of atmospheric nitrogen divides proportionally to the numbers  $9881 \times 0.96717$  and  $119 \times 1.376$ , which gives  $\frac{7.55}{1000}$  for the nitrogen and  $\frac{1.3}{1000}$  for the argon.

The centesimal composition of mean atmospheric air is consequently represented by the following table:

	Nitrogen.	Oxygen.	Argon.
By weight . . . . .	75.5	23.2	1.3
By volume . . . . .	78.06	21.	0.94

\* *Comptes Rendus*, November 2, 1896.

† A. Leduc. *Comptes Rendus*, August 4, 1890. The employment of the number 1.10506 for the density of oxygen led me, at that time, to 232.35. The difference seems to me to be due to experimental error.

# ON THE THEORY OF LUBRICATION AND THE DETERMINATION OF THE THICKNESS OF THE FILM OF OIL IN JOURNAL BEARINGS.

BY F. L. O. WADSWORTH, E.M., M.E.

*Concluded from Vol. CXLIV, p. 462*

## SUPPLEMENT.

### DETERMINATION OF THE SPECIFIC RESISTANCE AND TEMPERATURE COEFFICIENT OF OIL IN THIN FILMS.

*Introductory Note.*—Considering the length of time that has now elapsed since the article describing the results of the measurement of the resistance of films was written (see appended date), it has been thought best to leave it in the original form except for a few minor changes in wording or arrangement. Foot-notes have been added wherever it was thought desirable to make modifications or corrections.

Very little work seems to have been done in determining the specific resistance and temperature coefficient of the various kinds of oil. The only experiments which the writer has been able to find are those of Brooks\* on the *relative* resistances of a sample of paraffine oil for various temperatures between 4.4 C. and 93.3 C.† The experiments were made on a sheet of oil 3 millimeters thick, and about 2.3 square centimeters in cross section. No further data, however, was given from which the absolute resistance could be calculated, nor was it stated what particular kind of paraffine oil was used.

In the experiments recorded below, which have been undertaken as preliminary to the determination of the thickness of oil in journal bearings, the oil used was the best quality of commercial sperm oil, in which zinc had been placed for over a year in order to free it from any acid which it might contain. In addition to the determination of the absolute specific resistance and temperature coefficient, another object of these experiments was to determine whether there was any variation of specific resistance with variation in the thickness of the film,‡ or with the strength of current used.

### APPARATUS AND METHOD.

In order to obtain a thin, uniform film of oil of a determinate thickness, the following arrangement was used :

A pair of fine (Brown & Sharpe) surface plates, size about 4 x 6 inches, were placed one above the other, with their surfaces separated a short distance

\* "Wiedemann's Electricitat." Vol. II, p. 5.

† Since these experiments were made, a considerable amount of work has been done in determining the insulation resistance of various kinds of oil, particularly for the very high electromotive forces used in alternate current transmission.

‡ I did not learn of Reinhold and Rücker's results on the electrical resistance of thin soap films until some time after this work had been completed. (see also foot-note on final page.)



by pieces of thin sheet rubber or mica.\* At first the capillary attraction between the plates was relied upon to keep the film of oil uniformly spread between the two adjacent surfaces, but this being found sometimes unreliable, the two plates were immersed in a sheet-iron tank filled with the oil under experiment to a height just above the surface of the under plate (see *Fig. 4*). In order to avoid any danger of air bubbles in the film of oil between the plates, the upper plate was removed before beginning each series of experiments, and the oil heated to a temperature of about  $50^{\circ}\text{C}$ . The pieces of insulating material were then placed in position and the upper plate let down upon the lower one, care being taken to make the edges of the two plates exactly

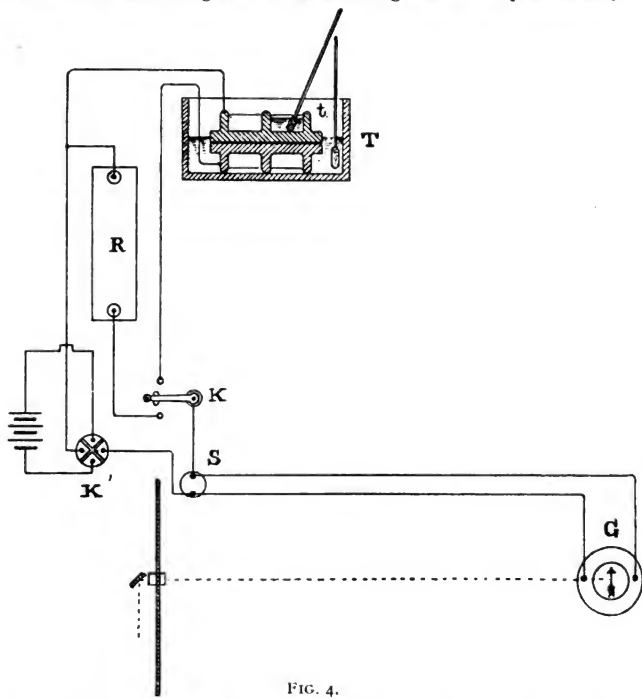


FIG. 4.

coincide. To drive out the bubbles of air which might cling to the surface of the upper plate when it was let down, the two plates were brought together with a quick, hinge-like motion. The plates and the tank of oil were then allowed to cool to the temperature of the room before beginning the measurements. The temperature was observed by means of two thermometers, one,

\* A method very similar to this in principle has since been used by Threlfall for obtaining the resistance of a thin film of sulphur.—*Phil. Mag.* 38, 452 (1889).

$T$ , immersed in the oil of the tank, the other,  $W$ , immersed in oil contained in the cavity of the upper surface plate. The resistance of the film of oil between the two plates was measured by comparing it with a 250,000-ohm box, by the method of deflections. The arrangement of the circuit is shown in Fig. 4, where

$G$  is a Thompson galvanometer of 6,000 ohms resistance.

$R$  is a 250,000-ohm box.

$T$  is the tank containing the two surface plates,  $t_1$  and  $t_2$ , arranged as before described.

$K$  is a three-way key for changing from the circuit through  $R$  to the circuit through  $t_1$  and  $t_2$ .

$K'$  is a reverse key for reversing the current in the battery circuit.

$S$  is a shunt in the galvanometer circuit.

Let  $G$  be the resistance of the galvanometer;  $R$  the resistance of the box;  $Q$  the resistance of the oil film;  $B$  the resistance of the battery and rest of the circuit (which may be neglected in comparison with either  $Q$  or  $R$ );  $S_1$  and  $S_2$  the shunts used respectively with  $R$  and  $Q$ ;  $d_1$  the deflection of the galvanometer when  $R$  is in circuit, and  $d_2$  the deflection when  $Q$  is in circuit. Then if  $d_1$  and  $d_2$  are not greatly different, it has been proven

$$\frac{R + G + B}{Q + G + B} = \frac{d_2}{d_1} \cdot \frac{\frac{G + S_2}{G + S_1}}{S_1} \quad (1)$$

or, since  $G$  is always very small in comparison with  $Q$ , and  $B$  may be neglected, we have

$$Q = (R + G) \frac{d_1}{d_2} \cdot \frac{S_2}{S_1} \cdot \frac{G + S_1}{G + S_2} \quad (2)$$

The resistance  $Q$  is made up of two factors: one the resistance of the oil film itself; the other the resistance of the insulating pieces which are used to separate the two plates. It has been found by direct experiment that the resistance of these pieces is so high that the measured resistance  $Q$  may be considered as produced by the oil film alone.\*

In order to determine whether variation in the current strength produced any variation in the resistance of the oil film, each film was tested with four currents, *i. e.*:

- |  |                           |
|--|---------------------------|
| (1) That produced by one Leclanché element,    | E. M. F. about 1.4 volts. |
| (2) Two Leclanché elements in series,          | E. M. F. " 2.8 "          |
| (3) Three bichromate elements in series,       | E. M. F. " 5.5 "          |
| (4) Twelve cells of storage battery in series, | E. M. F. " 25 "           |

The results are given in the tables which follow. As far as could be determined, there was no systematic difference corresponding to the differences in electromotive forces in the circuit.

When the thickness of the oil film was less than 0.01 inch some trouble was experienced from a gradual change in resistance, seemingly due to polarization of the oil film. Thus, with a film 0.01 inch in thickness, with three

\* The specific resistance of sheet rubber is nearly half a million times greater than that found for the oil under test, and the resistance of paraffine is even greater.

bichromate cells in series, and a  $\frac{1}{10}$  shunt in the galvanometer circuit, successive readings at intervals of one minute gave

Deflection right—368, 367·5, 367, 366·5, 366, 365·5, 364·5, 363·5, 363, etc.

Deflection left (battery reversed)—135, 136·5; after considerable interval—137

Deflection right—369, 368·5, 368, 368·5, etc.

To prove that this was not due to any change in the battery current,  $R$  was brought into circuit. The deflection both right and left remained perfectly steady for many minutes.

As the fall was very slow (only  $\frac{1}{2}$  div., or less than  $\frac{1}{2}$  per cent. of the whole deflection in a minute), only a very small error will be committed if the deflection is taken as soon as the oscillation of the needle due to closing the key  $K$  (which, as the needle is strongly damped takes place at the end of the second or third swing, or in from twenty to thirty seconds), has ceased. It is hardly necessary to add that in determining  $d_1$  and  $d_2$ , the usual precaution of reversing the battery current at each observation, and taking the mean of the two successive deflections (right and left) was always adopted. At frequent intervals the galvanometer circuit was also tested by reversal, to be sure that there were no errors introduced by thermal effects.

In the case ultimately under consideration (that of measuring the resistance of a film of oil between the moving surface of a shaft and the journal box), polarization would of course be prevented by a constant movement of the layer of oil.

#### DETERMINATION OF SPECIFIC RESISTANCE.

In order to obtain the specific resistance from the measurements of  $Q$  we must also know :

(1) The area of the conducting film. This will be, of course, the area of the plates, less the area of the supporting pieces, which was always 0·5 square inch.

(2) The thickness of the film. The thickness of the film was determined by the measurement of the thickness of the separating pieces. These pieces were measured very carefully by a Betts measuring machine, reading to 0·0001 inch. This measurement, however, might not always give the true average thickness of the film of oil for these reasons :

(a) Because of the compression of the pieces when in use by the weight of the upper surface plate, a compression which is increased by the preliminary heating and subsequent contraction of the oil and plates, the contraction of the oil film drawing the plates together and compressing the separating pieces in some instances by as much as ·001 inch, as determined by measurement of the pieces before and after using. To avoid this error the measurements taken were always those which were made after the pieces had been used.

(b) Because of inequalities in the thickness of the different pieces. The error due to this cause is very small, as care was always taken to select pieces which were originally of as nearly the same thickness as possible. The differences found on the measuring machine never amounted to more than 2 per cent., and were generally much less. Hence the average of the pieces could be taken as representing the average thickness of the oil film.

(c) Because of the deflection of the plates between the points of support. This deflection, although exceedingly small, cannot be considered as negligible when compared to the thickness of the very thinnest of these films, *i. e.*,



about 0.005 inch. To prevent this effect as far as possible, the supporting pieces were so placed that their distance from the center lines of the plates was

$$\frac{l}{2\sqrt{3}}$$

where  $l$  is the distance across the plate at right angles to the center lines.

(*d*) Because of inequalities in the surfaces themselves. Though the two surfaces are, in general, accurately plane, nevertheless, when considered in detail, they consist of a number of points which can readily be seen and distinguished by rubbing the plates together for a short time, until the points of contact become bright and polished. Between these points are shallow cavities, due to the scraping. The error due to this cause is of contrary sign to those due to (*a*) and (*c*); and its effect will be particularly considered later.

If  $A$  denotes the effective area of the oil film,  $a$  its thickness, and  $Q_t$  the measured resistance at the temperature  $t^\circ$ , we have for the specific resistance (C. G. S. units)  $\tau_t$  at this temperature, if  $A$  and  $a$  are expressed in inches:

$$\tau_t = 2.54 Q_t \frac{A}{a} \quad (3)$$

For the specific resistance at  $0^\circ$ , or at any standard temperature,  $t_0$ , we have:

$$\tau_0 = 2.54 Q_t \frac{A}{a} f(t - t_0) \quad (4)$$

where  $f(t - t_0)$  is the temperature coefficient of the oil.

To determine this function, the oil in the tank was heated to an initial temperature of about  $115^\circ\text{C}$ ., and then, after the whole had begun to cool uniformly, a series of simultaneous readings of temperature and resistance were taken while the oil and plates were cooling. As before, two thermometers were always used, one immersed in the oil-tank, and the other placed in a cavity filled with water in the upper surface-plate. The oil was kept thoroughly stirred, and the mean of the two readings, which (except for the higher temperature, while the plates were cooling rapidly) differed by only a slight amount, taken as representing the temperature of the oil film. For convenience, these measurements were made on the thinnest oil film used (thickness, about 0.005 inch), but there is no reason to suppose that the results would have been different for any of the other films.

#### DIMENSIONS OF APPARATUS.

The size of the surface-plates, as measured by a Brown & Sharp vernier caliper was 4.45 by 5.95 inches. The total area of the plates was therefore 26.5 square inches. The insulating pieces were always cut of such size that their combined area was, as already stated, 0.5 square inch. The area of the oil film was therefore 26 square inches. The films tested were of four different thicknesses, as follows:

*Series A.*—The insulating material was sheet rubber. Three pieces were used, of the following thicknesses:

	Inch.
No. 1, Average of six measurements gave . . . . .	0.01822
No. 2, " " " " . . . . .	0.01790
No. 3, " " " " . . . . .	0.01827

Average thickness of three pieces (= average thickness of oil film) . . . 0.01813

*Series B.*—The insulating material was sheet rubber. Four pieces were used, of the following thicknesses:

	Inch.
No. 1, Mean of six settings gave . . . . .	0.0601
No. 2, " " " " . . . . .	0.0613
No. 3, " " " " . . . . .	0.0602
No. 4, " " " " . . . . .	0.0615
Average thickness of pieces (= average thickness of film) . . . . .	0.0605

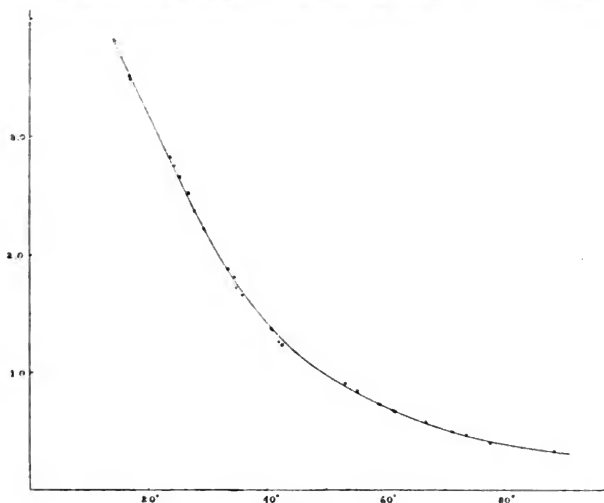


FIG. 5.

*Series C.*—The insulating material was paraffined paper. Four pieces were used, of the following thicknesses:

	Inch.
No. 1, Mean of six settings gave . . . . .	0.01019
No. 2, " " " " . . . . .	0.01017
No. 3, " " " " . . . . .	0.01030
No. 4, " " " " . . . . .	0.01017
Average thickness of pieces (= average thickness of oil film) . . . . .	0.01021

*Series D.*—The insulating material was paraffined paper. Four pieces were used, but unfortunately they were accidentally destroyed before they were measured on the Bett's measuring machine. They had been measured by a micrometer caliper before being used, and the thickness so obtained, which was 0.0075 inch, is probably correct within 2 or 3 per cent.

*Series E.*—Combined observations for specific resistance and temperature coefficient. The material used in this case was paraffined paper. Four pieces were used of the following thicknesses:

	Inch.
No. 1. Mean of six settings gave . . . . .	0.0046
No. 2. " " " " " . . . . .	0.00493
No. 3. " " " " " . . . . .	0.00467
No. 4. " " " " " . . . . .	0.00461
Average thickness of pieces (= average thickness of oil film) . . . . .	0.00462

The results of the measurements with these different thicknesses, and with the varying strength of battery current, are given in the following tables.

In order to reduce the observed resistances at different temperatures to a standard temperature, it is necessary to first determine the temperature coefficient from the observations of Series E. For this purpose these observations were first plotted (*Fig. 5*) and by the aid of a flexible steel strip a smooth curve was drawn, which represented most closely the experimental results. To represent this curve empirically an equation of the usual series form, *i. e.*,

$$Q_t = Q_0 [1 + A_1 (t - t_0) + A_2 (t - t_0)^2 + A_3 (t - t_0)^3] \quad (5)$$

was chosen, three terms being judged sufficient to represent the results over the range of temperature observed ( $90^\circ$  to  $15^\circ$  C.). In order to determine the values of  $Q_0$ ,  $A_1$ ,  $A_2$  and  $A_3$ , the theoretically best method is to form a series of observation equations by substituting in (5) the observed values of  $Q_t$  and  $t$ , and deduce from them four normal equations by the method of Least Squares. But in this case the observed points fell so nearly on the smooth trial curve that it was judged sufficient to determine the values of these constants directly from four carefully selected points on the trial curve. The points so selected were those corresponding to the four temperatures of  $20^\circ$ ,  $30^\circ$ ,  $50^\circ$  and  $80^\circ$ . The temperature selected as standard for these experiments was  $20^\circ$ , as being about the mean temperature of all the series taken, and as therefore involving the least chance of error in the reductions of the observations to this temperature. The value of  $Q_0$  is therefore at once determined. From inspection of the trial curve it was found to be

$$Q_{20^\circ} = 3.18 \text{ megohms.}$$

This value agrees almost exactly with that afterward found in reducing Series E, (see Table V).

For the other points we find

$$Q_{30^\circ} = 3.18 (1 + 10 A_1 + 100 A_2 + 1000 A_3)$$

$$Q_{50^\circ} = 3.18 (1 + 30 A_1 + 900 A_2 + 27000 A_3)$$

$$Q_{80^\circ} = 3.18 (1 + 60 A_1 + 3600 A_2 + 216000 A_3)$$

The values of  $A_1$ ,  $A_2$  and  $A_3$ , determined from these equations are, respectively:

$$A_1 = -0.038$$

$$A_2 = +0.00061$$

$$A_3 = -0.0000037$$

Equation (5) thus becomes

$$Q_t = 3.18 [1 - 0.038 (t - 20^\circ) + 0.00061 (t - 20^\circ)^2 - 0.0000037 (t - 20^\circ)^3] \quad (6)$$

The curve represented by this equation between  $t = 15^\circ$  and  $t = 90^\circ$  C. is plotted in *Fig. 5*. By inspection it will be seen that it represents the results of experiment very well; probably almost if not quite as well as it would had

the values  $A_1$ ,  $A_2$ ,  $A_3$  and  $Q_0$  all been determined by the theoretically more precise, but far more laborious process of Least Squares. Indeed in this case the amount of labor involved (as in many others where the Least Square process is commonly employed), would have been vastly disproportionate to the results achieved, and was therefore unwarranted by the accuracy of the observations themselves.

Between the points  $t = 15^\circ$  and  $t = 25^\circ$  (between which all the observations of the first four series lie) the curve corresponds almost exactly to a straight line, and can, therefore, be represented by a simpler expression of the form,

$$Q_t = Q_0 (1 - \beta t) \quad (7)$$

The mean value of  $\beta$  between these limits, as determined from the tangent to the curve at the point  $t = 20^\circ$ , is

$$\beta = 0.0343$$

The temperature coefficient of the oil is represented by the expression in the parenthesis of (6), or

$$f(t - 20^\circ) = 1 - 0.038(t - 20^\circ) + 0.00061(t - 20^\circ)^2 - 0.0000037(t - 20^\circ)^3 \quad (8)$$

or between  $15^\circ$  and  $25^\circ$  by the simpler expression from (7),

$$f_1(t - 20^\circ) = 1 - 0.0343(t - 20^\circ) \quad (9)$$

By the aid of (9) the observations in the five tables have been reduced to the chosen standard temperature of  $20^\circ \text{C.}$ , and the means taken as representing the mean resistance of the five films at  $20^\circ \text{C.}$  As before stated, three, and, in some cases, four sets of measurements were made in each series, with different strengths of battery current. It will also be noted from the remarks that the plates were separated and the insulating pieces readjusted several times during each set of measurements, that the conditions of experiment were varied in many other ways (such as applying and then removing pressure from the top plate, heating and cooling the plates when in position, varying the number of supporting pieces between the plates, etc.), and that each series extended over two or three days. Under these circumstances, and considering also the number of observations, it may be fairly considered, I think, that in the mean the accidental errors of experiment have been eliminated. For the same reasons the probable errors deduced from each set may be taken as fairly representing the accuracy of the results attained. None of the observations have been omitted save the first two in Series B, which were obviously considerably in error (probably sufficient time was not given the plates to cool down after the first setting, as it will be noticed that the resistance rose to a value very near the mean "after standing for some time undisturbed"), and one in series C, where the temperature was uncertain, having been taken too soon after heating. There are several that might have been rejected on Chauvenet's criterion and the apparent accuracy thereby considerably increased, but such an arbitrary treatment of the results of physical measurement, on purely mathematical grounds, and where there has been no apparent cause of suspicion registered at the time of making these particular observations, has always seemed to me a very dangerous and unwarranted proceeding.\*

\* I have since had no reason to change this opinion so far as reduction of one's own observations are concerned. When it is a question of combining a large number of observations by different observers, as is necessary in Coast Survey work, the case is somewhat different.



An inspection of these probable errors (see Table VI) shows, as might have been expected, that the accuracy of the determination decreases with the thickness of the film of oil. The error in the case of the thick film (Series B) is less than one-tenth of 1 per cent., while the largest error in the case of the two thin films is only one-half of 1 per cent., a degree of accuracy considerably greater than is necessary for the purpose for which these observations were originally made.

TABLE VI.

Series.	Mean Resistance 20°.	Error in Per Cent.	Thickness.	Specific Resist- ance at 20°.
			Inch.	Megohms per c.c.
B . . . . .	33 635 ± '030	0'0009	0'0638	36500
A . . . . .	10 63 ± '030	0'0025	0'0181 +	35700
C . . . . .	6 86 ± '032	0'0046	0'0102 +	44300
D . . . . .	4'98 ± '026	0'0051	0'0075 (?)	43800
E . . . . .	3'18	about '005 †	0'00462 —	45400

† As judged from the divergence of the observations from a smooth curve.

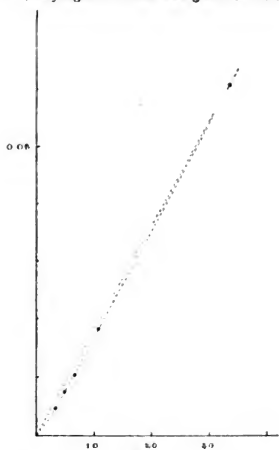


FIG. 6.

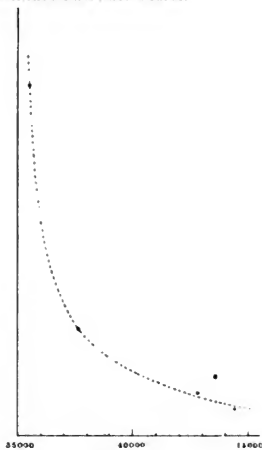


FIG. 7.

When we calculate the specific resistance from these results, we find an interesting result, viz.: that the specific resistance increases regularly as the thickness of the film decreases. This is shown in Table VI, and better in *Figs. 6 and 7.*

In *Fig. 6* the means of the different series are plotted as a function of the thickness, and in the second the absolute specific resistance calculated from

these first results are plotted in the same way. With the exception of the one result from Series C, the points all lie on a smooth curve, which, in the first case, passes through the origin, and, in the second, appears to be asymptotic to the two axes of  $\sigma_0$  and  $a$ . The variation is of too regular a character to be accidental. I had, indeed, anticipated that such a result might be obtained before beginning the experimental work, and it was for that reason that I chose to work on films as thin as I could conveniently obtain, rather than on the oil in mass. A change in specific resistance is what we might expect with decrease of thickness, because of the effect of one surface upon the other, particularly when the thickness of the film approaches the range of molecular attractions. No such limit has yet been reached here, yet it would seem that such an effect is beginning to be felt. It is possible that these results may be explained by considering that the effective thickness of the oil film is greater than the thickness of the supporting pieces on account of the cavities due to the scraping of the plates, although such an effect is directly opposed to the effect of causes (*a*) and (*c*) both of which tend to decrease the thickness of the film. In order to determine whether this explanation is sufficient to account for the differences I have observed, I have assumed that the effective thickness of each film is  $a + x$ , where  $x$  is the mean correction required to the measured thickness  $a$ , on account of the cavities in the plates. To determine  $x$  we take the two extreme values of  $Q_0$  given in Table VI, and equate the values of  $\sigma_0$  obtained from them. This gives us

$$\frac{\text{Series B.}}{33.635} = \frac{\text{Series E.}}{3.18} \\ \frac{0.0608 + x}{0.0462 + x}$$

Whence

$$x = 0.00124.*$$

For the corrected thickness and specific resistance we then obtain :

Series.	Corrected Thickness. Inch.	Corrected Specific Resistance. Megohms per c.c.	$\delta$ .
B	0.06205	35750	0
A	0.01938	36200	+ 450
C	0.01145	39400	+ 3650
D	0.00875	37500	+ 1750
E	0.00587	35750	0

From this table it will be seen that while the first and last results are reconciled by this assumption, all the others are still large, and what is more, the divergence is systematic and symmetrical. If the differences were fully accounted for by the assumed correction  $x$  to the thickness, the positive and negative differences from the mean ought to have been irregularly distributed.\*

The most conclusive way, however, of determining whether this explana-

\* A further objection to this method of explaining the observed variation in  $\sigma$ , is the large value of  $x$  necessary. According to Reynolds (see p. 184 of paper already referred to), the irregularities in a well-scraped surface ought not to be greater than 0.0001 inch, and the maximum correction, therefore (supposing the hollows in the two plates to all come opposite each other!!!), ought not to be more than 0.0002 inch, at the most—only one-sixth that which it is found necessary to assume.

tion is the true one or not, is to use two surfaces which have been ground together after scraping, so as to obtain two perfectly *smooth* as well as *true* surfaces. Unfortunately, I was not able to do this, because the plates were the property of the Mechanical Department. As soon as possible I intend to make a pair of plates for myself, and repeat the experiment.\*

In conclusion, I wish to express my thanks to Professor Thomas for the use of his instruments and laboratory, and to Professor Robinson for the loan of the surface plates.

PHYSICAL LABORATORY, OHIO STATE UNIVERSITY,  
COLUMBUS, December, 1888.

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## NOTES AND COMMENTS.

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### A NEW DEPARTURE IN THE TESTING OF METALS.

In a circular announcing the opening of testing laboratories in Boston, Mr. Albert Sauveur gives much prominence to the microscopical examination of metals. It is the first public laboratory thoroughly equipped to carry on this new and promising method of testing, and, as the subject is at present receiving much attention in the metallurgical world, Mr. Sauveur's statements are of interest to the reader. He expresses himself as follows:

This new science, which has been called "microscopic metallography," has made remarkable progress in recent years, and it is confidently believed that those metallurgists who have kept in touch with its developments will admit that it is destined eventually to stand side by side with the chemical analysis of metals in importance and usefulness. The two methods of testing will complement each other. Concerning that all-important factor, the heat treatment, which contributes so powerfully to the final properties of the metal, chemical analysis can tell us nothing. This is the domain which belongs to the microscope, and in which its usefulness will become more and more appreciated.

It must be borne in mind that the physical properties of a sound piece of steel depend exclusively upon its chemical composition and upon its structure, and that the structure itself is the resultant of two factors—the composition

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\* When I spoke of these results to Professor Michelson, about a year after they had been obtained, he told me that he had found a similar result in the case of gold or silver films (I have forgotten which), *i. e.*, that the specific resistance of the metal, as determined from these thin films, was very much higher than the value obtained from wires or strips. This strengthened my belief still further in the reality of the observed change. Still further evidence in this direction has been afforded by the recent results of Reinhold and Rücker, on the electrical resistance of soap films. In their first work on this subject, these authors found (see *Phil. Trans.*, 1883, Section A) that in soap films made from a solution containing 3 per cent. of  $\text{KNO}_3$  in solution, the specific resistance "is the same whether the liquid be examined in bulk or in the form of a film  $12 \mu$  (0.00048 inch) in thickness." But more recently (*Proc. Royal Soc.*, Vol. 53, p. 394), they have found that when the salt is omitted from the solution, the specific resistance changes with change in thickness, although in this case it diminishes, *i. e.*, the electrical conductivity increases as the film grows thinner.

and the treatment which the metal has undergone. It is, therefore, of as much importance to know what the structure of the metal is as to know what its chemical composition is, in order to arrive at accurate conclusions regarding its quality, provided we can interpret the appearance of the structure intelligently. The microscope gives us a means, moreover, of ascertaining in most cases what the past heat treatment of the metal has been. The microstructure of steel is extremely sensitive to slight changes of heat treatment. To each temperature corresponds a certain structure which has its own physical properties—in other words, if a piece of steel is heated to a temperature slightly different from that of its previous treatment, it assumes a different structure, and its physical properties are consequently altered.

Attention has been called quite recently to the fact that when steel contains about 0.90 per cent. of carbon and practically no other impurities, its structure is made up of a single constituent (pearlyte), whereas with less carbon, or when more highly carburized, the structure is composed of two constituents (pearlyte and ferrite in the one case, pearlyte and cementite in the other). This point, which has been called the "saturation point" of steel, is an important one. The structure of the metal is here more homogeneous than it is for any other degree of carburization. It is found, however, that the presence of impurities exerts a great influence upon the position of the saturation point—that is, upon the amount of carbon necessary to saturate the steel. When, for instance, about 1 per cent. of manganese is present, 0.80 per cent. of carbon, or even less, is sufficient to produce the structural saturation. It is probably true that all impurities lower the saturation point, but in a very different degree. A steel made up of a single microscopical constituent (although a binary one) must for certain purposes present serious advantages over other grades of steel, and in the present state of our knowledge the microscope alone can tell us when the saturation point has been reached. As further experiments throw more light upon the properties (and, it is believed, superiority) of saturated steels information regarding the exact saturation point of steel of various compositions may become of great importance and be frequently sought.

It is proposed to carry on two distinct classes of microscopic tests. Class I will include microscopic examinations with a view of ascertaining the general character of the structure. The report will give a description of the appearance of the structure, stating the absence or presence of blowholes, slag, flaws or any other feature of an abnormal character, giving qualitative information regarding the quality of the metal and its past treatment—whether hardened, tempered or annealed; whether cast or forged; whether finished at a high or low temperature; whether hot worked or cold worked in the case of cold-drawn or cold-forged metal; whether the generally detrimental effect of cold work has been or not entirely removed by a subsequent annealing, etc.

Class 2 will give a very complete microscopical test, including the taking of a photomicrograph of the microstructure of the metal magnified to a suitable dimension (up to 1,000 diameters), and planimeter measurements of the microscopic constituents, their amounts being stated in percentages of the total area of the microscopic field, and the average size in which they occur being also given. By means of such measurements and by referring to the structure of standard specimens, information is derived regarding the quality and past

treatment of the metal of a somewhat quantitative character. If the metal was hardened, the position of the quenching temperature with regard to the critical points can be ascertained. If forged, and if the dimensions of the piece are known, the temperature at which it was finished can be stated quite closely. If the last treatment was a re-heating or an annealing, followed by slow cooling, the temperature at which such operation was performed can be inferred from the microstructure. Where pieces of iron and steel have failed by rupture or in any other way, and it is desired to test them microscopically, the piece itself should be sent; or, if too bulky, a portion from the vicinity of the fracture and including it, together with the fullest possible particulars.

Experiments of any description dealing with the heat treatment and physics of iron and steel will be undertaken to ascertain how the structure and physical properties of a certain steel are affected by a certain treatment. The position of the critical points of any steel will be determined with great accuracy, and it is firmly believed that, as the metallurgy of steel becomes a more exact science, the determination of the temperatures at which such important changes occur in the nature of the metal will become of greater moment, and will be frequently needed. Due regard to the critical points during the treatment which steel receives in the process of manufacture of the finished product would, no doubt, result in raising its quality and reliability.

---

#### TIN SCRAP.

The *Iron Age* conveys the information that there is a very large and steady export movement of tin scrap from the Atlantic coast to Europe. The amount of tinplate clippings made by the large tinware and can-making factories of the country is very considerable. Some of the more extensive works in this line put out from 50 to 100 tons of scrap tin monthly. This material, in most instances, is sold to exporters under a yearly contract. It is baled at the factory and shipped to Antwerp, from whence it is sent to a separating works in Holland, where, by a special process, the tin is recovered and made into pigs, while the steel scrap is sold for various purposes. The average value of the tinplate scrap, in bales, delivered at the dock in New York, is about \$5 a ton. Some of the smaller tinware factories, which have no facilities for baling their scrap, dispose of it loose to the manufacturers of sash weights.

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#### THE LIQUEFACTION OF FLUORINE.

In a recent impression of (London) *Nature*, a correspondent, W. J. P., has the following to say on this subject:

Fluorine was prepared for the first time in 1886 by Prof. Moissan, as a product of the electrolysis of anhydrous hydrogen fluoride contained in a platinum apparatus provided with fluorspar stoppers. The new gas was at once found to be the most active chemical substance known, many elements and organic compounds, such as arsenic, antimony, sulphur, iodine, alcohol, and turpentine, immediately and spontaneously bursting into flame when plunged into an atmosphere of fluorine. On mixing the gas with hydrogen, even in the dark, a violent detonation immediately occurs, hydrogen fluoride being

produced. The violent action of fluorine upon nearly all substances with which it is brought into contact obviously renders extremely difficult all experimental work involving the use of the free element. The great manipulative difficulties necessarily arising whilst dealing with the gas on a large scale have, however, been very happily surmounted by Prof. Moissan and Prof. Dewar, who recently described to the Chemical Society the method by which they have succeeded in liquefying fluorine, and determining the more important properties of the liquid substance (*Proc. Chem. Soc.*, November 4, 1897, p. 175). It seemed likely that the great chemical activity of fluorine might so far decrease at low temperatures as to allow of the manipulation of the material in a glass vessel cooled in liquid air; this was found to be the case.

The fluorine required in the work was prepared by the electrolysis of anhydrous hydrogen fluoride; this liquid, being a non-conductor, was made a conductor by dissolving in it potassium fluoride. The liberated fluorine was freed from hydrogen fluoride by being passed first through a platinum worm immersed in a cooling mixture of solid carbon dioxide and alcohol, and subsequently through platinum tubes containing dry sodium fluoride. The purified gas was then passed down a vertical platinum tube fused to the neck of a thin glass bulb, which served as the collector, and an exit was provided through a narrower platinum tube contained inside the first. On cooling the apparatus down to  $-183^{\circ}$  in boiling oxygen whilst the fluorine is passing through, no liquefaction occurs, but, on reducing the pressure under which the oxygen is boiling, and so lowering the temperature to  $-185^{\circ}$ , the fluorine condenses in the glass bulb to a very mobile yellow liquid; on removing the bulb from the cooling bath, the liquid fluorine boils vigorously. Other experiments made with boiling liquid oxygen and liquid air as refrigerating agents indicated that fluorine boils at about  $-187^{\circ}$ , namely, at the boiling point of liquid argon; from this the probable critical temperature and pressure of fluorine are deduced as  $-120^{\circ}$  and 40 atmospheres respectively.

At these low temperatures fluorine is without action on glass, and does not displace iodine from iodides; silicon, boron, carbon, sulphur, phosphorus and reduced iron, all of which spontaneously ignite when brought into contact with fluorine at ordinary temperatures, do not inflame if, after being cooled in liquid oxygen, they are plunged into an atmosphere of fluorine. Hydrogen gas inflames spontaneously, with considerable evolution of light and heat, when directed on to the surface of liquid fluorine at  $-190^{\circ}$ ; on passing fluorine on to solidified turpentine cooled by boiling liquid air, a series of explosions occurred, resulting in the destruction of the apparatus. It thus seems that the great affinity existing between hydrogen and fluorine is not overcome at  $-190^{\circ}$ . A little liquid fluorine falling on the floor instantly inflames the wood. Fluorine is soluble in liquid oxygen, and on passing in the gas a white flocculent precipitate is formed, which, after filtering off, deflagrates violently as the temperature rises; it is possibly a hydrate of fluorine.

Determinations made by floating pieces of various substances in liquid fluorine indicate that its density is about 1.14, and from the invisibility of amber immersed in the liquid, the refractive index of the latter would seem to be higher than that of liquid air or oxygen. Liquid fluorine shows no magnetic phenomena when placed between the poles of a powerful electro-magnet;

it has a smaller capillarity constant than liquid oxygen, and does not solidify at  $-210^{\circ}$ . It has no absorption spectrum, and its color is the same as that of the gaseous element.

#### ELECTRICITY ON STEAM ROADS.

In a recent address before the New York Railroad Club, Dr. Hutchinson discussed at length the subject of the application of electricity to the operation of main lines of railroad. His comments were decidedly unfavorable, and his conclusion was that the improvements made during the past fifteen years had not substantially advanced the electric motor for this branch of railway service.

While it is doubtless true that the advocates of electricity have made extravagant claims for the electric locomotive, there will be found among progressive railroad engineers few who will be willing to endorse so sweeping a condemnation of the third-rail system as that above referred to.

W.

#### BOOK NOTICES.

*Encyclopédie des Aide-Mémoire.* Librairie Gauthier-Villars et Fils. Paris: (Small 8vo. Price per volume, 2.50 francs, unbound; 3 francs, bound.)

Since our last notice of this condensed series of technical hand-books, the following additional volumes have appeared. As previously noticed, each of these volumes treats of a special subject, and is substantially complete in itself:

*Henriet (H.)*, ancien Élève de l'École de Physique et de Chimie industrielles de la Ville de Paris, Chimiste à l'Observatoire de Montsouris. Les gaz de l'atmosphère.

*Vallier (E.)*, Chef d'escadron d'Artillerie, Correspondant de l'Institut. Projectiles de campagne de siège et de place. Fusées.

*Lefevre (Julien)*, Professeur à l'École des Sciences et à l'École de Médecine de Nantes. Eclairage aux gaz, aux huiles, aux acides gras.

*Loppé*.— Accumulateurs électriques.

*Lefevre (Julien)*, Professeur à l'École des Sciences et à l'École de Médecine de Nantes. Eclairage électrique.

*Urbain (V.)*, Ingénieur des Arts et Manufactures, Répétiteur à l'École Centrale. Les succédanés du chiffon en papeterie.

*Fabry (Ch.)*, ancien Élève de l'École Polytechnique, Maître de conférences à la Faculté des Sciences de Marseille. Les piles électriques. W.

*Stamp Milling of Gold Ores.* By T. A. Rickard, Mining Engineer and Metallurgist, Fellow of the Geological Society, etc., etc. New York : The Scientific Publishing Company. Cloth, illustrated, price \$2.50, 1897.

The author, whose familiarity with the subject of "Stamp Milling." is well known through his extensive contributions to current technical journals, has elaborated into the form of the present work a series of articles on the subject which originally appeared in the *Engineering and Mining Journal* and *The Mineral Industry*.

The work embodies the results of the author's practical work and observations of the methods employed in the principal gold mining districts of the world, and may be regarded as the critical expression of the views of a competent expert. It is written in plain, comprehensible style, and with the avoidance, as far as possible, of the discussion of chemical reactions and other strictly scientific data, with the view of making it of present use to those engaged in the actual work of the mill as well as to the student and teacher. In a word the book is a painstaking description of the best specimens of gold-milling practice in every part of the world.

W.



# Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, December 15, 1897.*]

HALL OF THE FRANKLIN INSTITUTE,  
PHILADELPHIA, December 15, 1897.

Vice-President H. R. HEYL in the chair.

Present, 73 members and visitors.

Additions to membership since last report, 12.

In accordance with Article XV of the By-Laws, nominations for officers, managers, and committeemen were made, as follows:

For <i>President</i>	(to serve one year), . . . . .	JOHN BIRKINBINE.
" <i>Vice-President</i>	( " three years), . . . . .	GEORGE V. CRESSON.
" <i>Secretary</i>	( " one year), . . . . .	WM. H. WAHL.
" <i>Treasurer</i>	( " " ), . . . . .	SAMUEL SARTAIN.
" <i>Auditor</i>	( " three years), . . . . .	JOHN GEORGE COPE.
" "	(for the unexpired term of J. H. Cooper, deceased), . . . . .	WM. H. GREENE.

For *Managers* (to serve three years).

GEORGE H. FRAZIER,	ALEX. KRUMBHAAR,
ALFRED C. HARRISON,	C. HARTMAN KUHN,
HENRY R. HEYL,	SAMUEL M. VAUCLAIN,
HERBERT M. HOWE,	GEORGE VAUX, JR.

For the *Committee on Science and the Arts* (to serve three years).

L. I. CHENEY,	J. LOGAN FITTS,	LINO F. RONDINELLA,
JAMES CHRISTIE,	CHAS. A. HEXAMER,	A. J. ROWLAND,
LUIGI D'AURIA,	JACOB V. MCCONNELL,	SAMUEL SARTAIN,
J. M. EMANUEL,	CLAYTON W. PIKE,	T. CARPENTER SMITH,
WM. PENN EVANS,	STACY REEVES,	THOMAS SPENCER.

Mr. Arthur Kitson, a member of the Institute, presented a communication describing an improved incandescent light of his invention. The inventor utilizes for the purpose a mantle similar to the Welsbach, and employs as the illuminant high fire-test petroleum, which is first vaporized by the heat of the flame and burned in an air-blast, giving a blue flame similar to that of the Bunsen burner. The flame produces an intense heat and a brilliant illumination of the mantle. The method is specially adapted for lighting large areas and for street lighting, and is claimed to be remarkably cheap, when compared—light for light—with other methods of lighting for similar applications.

The subject was referred, for investigation and report, to the Committee on Science and the Arts.

The Secretary's report followed, and the meeting adjourned.

WM. H. WAHL, *Secretary*.

## COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held December 1, 1897.*]

MR. JAMES CHRISTIE in the chair.

Reports on the following subjects passed first reading :

Wave Motor, Lotzgesell, Philadelphia.

Process and Apparatus for Manufacturing Carburetted Water Gas, Henry C. Reed, Chicago, Ill.

Steel-Lined Aluminum Culinary Ware, Romaine C. Cole, New York.

Reports on the following subjects were adopted :

*Perpetual Power with Manageable Air-Ship.*—J. A. Klefser, Philadelphia.

ABSTRACT.—The inventor's object is to supply a continuous motive force for driving machinery, ships, etc., by the use of water, compressed air, or balls. The report condemns the plans proposed as impracticable. [*Sub-Committee.*—G. M. Eldridge, Chairman ; J. M. Emanuel.]

*Duplication of the Cube.*—Charles Morrell, Chicago, Ill.

ABSTRACT.—The method submitted by Mr. Morrell purports to be an exact means of determining, by a graphical construction, the length of the edge of a cube when volume is twice that of a given cube.

A rigorous mathematical analysis of the demonstration offered by Mr. Morrell showed that the volume of the cube thus obtained differed from the value claimed for it by about  $+0.003$  of the true value, the percentage of error being, therefore, three-tenths of 1 per cent., and the percentage in the linear dimension about one-tenth of 1 per cent., or so small as to (probably) escape detection by ordinary means of measurement. The report concludes that "the proposed method is mathematically defective, nor is its practical value apparent in view of the fact that by the aid of tables of logarithms, or of cubes, a more accurate determination can be made in less time. It deserves to be recorded, therefore, simply as an interesting fact, that by the graphical method \* \* \* the so-called 'duplication of the cube' can be effected with a degree of accuracy, practically speaking, no less than that characteristic of graphical methods in general. [*Sub-Committee.*—Edgar Marburg, Chairman ; Edwin S. Crawley, L. F. Rondinella, Hugo Bilgram.]

*Investigations with the Electric Furnace.*—Henri Moissan, Paris, France.

ABSTRACT.—This report is in substance an historical *résumé* of the researches of M. Moissan in the chemistry of high temperatures, conducted with various forms of the electric furnace.

The report has been referred to the Committee on Publications for publication in full. The award of the Elliott Cresson Medal is suggested, and is now under advisement. [*Sub-Committee.*—Paul A. N. Winand, Chairman ; Charles J. Reed, Harry F. Keller.]

*Improvement in Tidal Powers.*—Ernst Markmann, Philadelphia.

ABSTRACT.—This invention is explained to consist of a novel construction of apparatus for deriving power from tide-water, the idea being to utilize the flow of tide-water into certain basins at high tide, and back from these basins at low tide, through turbines mounted on a float. Admission and outflow of water is regulated by the interposition of a special system of gates. For the

mechanical details of this construction the reader is referred to the inventor's letters-patent filed with the report.

The complex arrangement of gates used to direct and control the water in these basins is claimed to be an important feature of the invention, but the main feature to which the attention of the investigating committee was directed is the floating turbines. On this point the report speaks as follows: "By means of the float, on which the wheels are mounted, they are kept at the lower level for the purpose of utilizing the full height of the fall, regardless of the well-known fact that the difference of level measures the working head, no matter where the turbines may run in the course of the flow, within the limit of atmospheric pressure." The conclusion is reached that the invention presents no advantages on the score of utility. [*Sub-Committee.*—Wilfred Lewis, Wm. M. Barr.]

*The Phantoscope.*—C. Francis Jenkins, Washington, D. C.

ABSTRACT.—This invention relates to an apparatus for projecting upon the screen a series of photographs of moving objects taken in such rapid succession that when reproduced upon the screen the scenes and movements are in effect realistic. It is the subject of letters-patent of the United States, Nos. 536,569, 560,800 and 585,593, granted to Mr. Jenkins, to which the report makes reference for numerous details of the projection apparatus.

The report sketches the progress during the past thirty years of the art of reproducing on the screen, by various attachments to the "magic lantern," of a series of photographs of moving objects taken in more or less rapid succession; but sets forth that "but little of practical value could result until flexible films were invented, by the use of which consecutive photographs of indefinite number could be made and reproduced as positives on like films, which could be automatically passed between the lenses of a projecting lantern."

Reference is made to the contributions made to this branch of applied photography by Brown (U. S. letters-patent, August, 1869), and to the researches of Messrs. Muybridge, Renaud, Marey and Anschütz (1877-1887) in their efforts to analyze and illustrate the movements of man and animals, and a brief description of the methods employed by these investigators for making rapid, consecutive photographs is given.

The report then proceeds to consider Mr. Jenkins' contributions to this subject (commenced about 1890). These comprise the various instruments that are needed, first, to take photographs in rapid succession on a moving ribbon or flexible negative film, for making positives therefrom, and two forms of the so called phantoscope, or apparatus employed to project the series of pictures upon the screen in very rapid succession, and with realistic effect.

These devices are highly refined, and display much ingenuity in the means employed in achieving the desired effect of projecting the series of pictures on the screen in extremely rapid succession, and with the practical suppression of the flickering that constituted a serious objection to previous efforts in this direction. The details, however, could not be made intelligible without the aid of illustrations, for which reason the reader is referred to the report itself and documents filed therewith. The award of the Elliott Cresson Medal to the inventor is suggested, and is now under advisement. [*Sub-Committee.*—H. R. Heyl, Chairman; John Carbutt, Geo. A. Hoadley.]

## SECTIONS.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, December 8, at 8 P.M., Mr. Benj. Smith Lyman, President, in the chair.

Paper of the evening: "Fatigue of Metal in Iron and Steel Castings," Mr. H. F. J. Porter, Bethlehem Iron Company, South Bethlehem, Pa. (Discussion.) Referred to the Committee on Publications.

Nominations for officers for the year 1898 were made.

ELECTRICAL SECTION.—*Special Meeting*, December 14, 8 P.M., Mr. Clayton W. Pike, President, in the chair.

Papers of the evening: "Speed Government in Water-Powers," Mark A. Replogle; "Transmission of Power by Constant Current in Practice," Mr. Paul A. N. Winand. (Discussion.) Mr. Replogle's paper is referred for publication.

The following were elected officers of the Section for 1898: President, Mr. W. E. Harrington; Vice-Presidents, Mr. Theodore Spencer; Mr. G. U. G. Holman; Secretary, Mr. John A. Lafore; Conservator, Dr. Wm. H. Wahl.

CHEMICAL SECTION.—*Stated Meeting*, December 21, 8 P.M., Vice-President Dr. Bruno Terne in the chair.

Paper of the evening: "The Chemistry of California Petroleums," Prof. S. F. Peckham, Ann Arbor, Mich. (Read by Prof. S. P. Sadtler.) Discussion, Referred for publication.

Officers for the year 1898 were nominated.

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\*Science and the Mechanic Arts.\*

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SELLERS, E.D., Committee on Publications:

with the Assistance of

DR. WM. H. WAHL, Secretary of the Institute.

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*Vol. CXLV, No. 2. 73d YEAR. FEBRUARY, 1898*

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THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

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## ELECTRICAL SECTION.

[*Stated Meeting, December 14, 1897.*]

MR. CLAYTON W. PIKE, President, in the chair.

### SPEED GOVERNMENT IN WATER-POWER PLANTS.

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BY MARK A. REPLOGLE.

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No problem in hydrodynamics has created so much interest in the past few years as the government of water-powers. When it had been demonstrated that power could be successfully transmitted to great distances by the use of electric currents, the economist very naturally conceived the idea of harnessing available waterfalls. It was well known that turbine water-wheels could be constructed that would furnish to a dynamo an efficiency of 75 per cent., or more, of the energy represented by the fall or head. The conservative engineer and the investor, however, were much concerned about the

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possibilities of regulation or government, and much diversity of opinion has been expressed by thoughtful and earnest engineers regarding it. Specialists have spent much labor in experimenting and developing apparatus to govern power plants. It has been demonstrated that water-power plants can be successfully governed. But the various degrees of regulation, ranging from indifferent speeds up to good engine practice, even with the same apparatus when used in different water-powers, prove that there are some underlying principles that must be adhered to if successful regulation is to be obtained by calculation or intelligent reasoning, and it is for the purpose of discussing some of these principles that this paper has been prepared.

Very little literature can be found that treats on the government of water-powers in a scientific manner, and what is extant shows that the German, Swiss and French engineers had spent much thought and labor on this subject years before the problem became an important one in America. Space forbids any comments on their experiments or practice, except to say that, until within a very few years, they were far in advance of our own hydraulic engineers in this particular part of power-plant construction.

Regarding the *early* work in this line, nothing better can be said than to quote the "Encyclopædia Britannica," which says: "The science of hydrodynamics was cultivated with less success among the ancients than any other branch of mechanical philosophy. If we except a few propositions on the pressure and equilibrium of liquids, hydrodynamics must be regarded as a modern science which owes its existence and improvement to those great men who adorned the seventeenth and eighteenth centuries." During the early part of the nineteenth century rapid advances were made by Europeans in methods of getting power from gravity by the use of the agent water. The interest awakened by the success attained, as well as the necessity of good government in localities where steam power was expensive, no doubt had much to do toward an early development of governing apparatus in the European countries. In America, steam-power has been so

cheap as almost to supersede water-power in some localities, and where steady power was a necessity it was almost invariably furnished by steam engines, water-power being used only where little or no government was required. Hence the American manufacturer was fairly satisfied with a device that would slowly move his wheel gates when too great a change was perceptible in the speed of his plant. Such device was called a governor until the electrical engineer of recent years discovered that his machinery was safer if he ignored entirely the so-called water-wheel governor.

The late successes in long-distance transmission make water-powers more valuable than they have been considered in the past, and the demands for reliable speed regulation are so urgent that there is a decided tendency on the part of engineers and investors to study the proposition more from a scientific point of view, laying bare, if possible, the principles that underlie it. These principles then may be used for foundations from which to reason out a solution of the problem. The doubts concerning the satisfactory government of water-power have often caused capital to be withheld where it otherwise might be earning handsome dividends. It is very apparent that speed government in water-powers should be reduced to an exact science, if possible, and it is hoped that this paper will exert some bearing to that end.

The following preliminary view of the proposition will disclose some of the difficulties that do not appear at first thought: First to be considered is the water. It is an inert material, incompressible, and having inertia, hence momentum when in motion. It contains no power whatever except that generated by gravity in giving it motion. Perhaps no better demonstration of the evil effects of inertia and momentum in governing can be given than the experience at the power plant of the Fresno transmission. (*Plate I.*)

A feeder pipe about 3,800 feet long is used to carry the water from *A*, the outlet of a reservoir on a mountain top, to *D*, the power house on the San Joaquin River. The fall or head in this case is 1,410 feet, and the pipe is amply heavy for all the ordinary strains that come in the manipulation of the

power. Before the plant was ready for actual operation, through some accident, a valve at *D* was opened, allowing a 4-inch stream of water to escape; the pressure gauge, which ordinarily showed 610 pounds to the square inch, dropped to 350. The valve at *D* was almost immediately closed by the attendant when the pressure-gauge pointer ran up to its limit, 1,000 pounds to the square inch. Immediately following this was a great writhing in the pipe line, ending in a report at *C* about 700 feet vertically above the power house. The pressure gauge dropped to about 300, and the flood of water coming down the mountain side indicated that the pipe had burst at *C*.

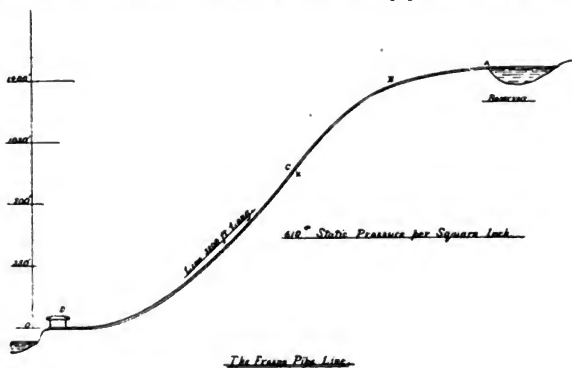


PLATE I.

Further investigation showed that the pipe from *A* to *B* had collapsed or flattened. The logical conclusion is, that when the valve was opened at *D* the portion of the water column from *B* to *D* began moving. That portion of the column from *A* to *B* lying in an almost horizontal plane did not have its inertia overcome quickly enough to follow, hence the column separated at *B*, causing a vacuum from *B* to *C*. When the valve at *D* was closed the water from *D* to *C* came to a standstill, raising the pressure by its momentum to 1,000 pounds per square inch, showing proof that the engineers had calculated correctly. By the time that the valve was closed at *D*

the column *A B* had been acted upon by gravity for some seconds, thereby giving it time to acquire considerable velocity, hence momentum; therefore, when it reached the other column at *C* the concussion burst the pipe, showing at one bold stroke the effect of incompressibility and momentum. The collapse in the pipe from *A* to *B* was due of course to the water emptying faster at *C* than it could enter at *A* (the pipe line here being of much lighter steel).

It can readily be seen that if government in this plant were attempted by changing the flow in the pipe line, as is ordinarily done, it would have been an impossibility if the safety of the installation was a consideration. Hence the governing is done by shifting a stream of water on or off the wheel as the power-demands require.

It might be added incidentally that the stream from a nozzle  $1\frac{3}{8}$  inches in diameter furnishes about 500 horse-power, also that said stream can very quickly bore a hole through a granite rock or even a steel plate. It requires much care and ingenuity to handle this power plant, but it has been in actual operation for nearly two years, and is an unqualified success.

The inference to be drawn from the above experience is, that these evil effects appear in every power plant in a corresponding ratio to the length of pipes or closed flumes used to carry water to wheels. The injurious effect on government is to *change* momentarily the pressure or head on the wheel when any movement of the wheel gate is made. The effect is always the opposite from that required to keep even speed. Hence there is a limit to the time allowable in the gate movement.

The second factor to be considered is the water-wheel itself. It has a possible range of speed from zero to even faster than the spouting velocity due to the head, and it is unlike a steam engine in many respects. Its periphery must move at a velocity that is a proper ratio to the spouting velocity of the head, in order to gain the highest efficiency of power. The wheel also allows practically the same quantity of water to pass through it at any of its possible speeds. If any difference, it allows more water to pass through it at under-speed than it does at overspeed. So it can be readily seen *that*

*an accurate gauging of the water that enters the wheel does not necessarily have anything to do with the speed.* The speed of wheel is the result of quantity of water combined with pressure on one hand and load of work on the other. Therefore, any change in one of these three factors causes a change in the speed. .

If a wheel at the end of a long-closed pipe containing hundreds of tons of water were running at normal speed, carrying a certain load, its speed would remain constant if no changes were made in the conditions. If, however, the gates were *slowly* opened, its speed would be increased by the greater quantity of water entering it. If, instead of this, a part of the load were dropped off, the speed in like manner would rise. If the gates were *slowly* closed the speed would soon begin to fall. But if the gates were *rapidly* closed the momentum of this column would cause a much greater pressure at the wheel-gate openings, and for an instant cause practically the same amount of water to enter the wheel at higher velocity. This amount of water having higher velocity will contain more energy or power for the time being, and of course will impart more to the wheel, increasing its speed slightly for a short time instead of immediately decreasing it, as would seem natural. This tendency for an increase in speed, added to the increase already caused by a part of the load being dropped, will make it necessary for a greater amount of work to be done by a governor than would be proper after the momentum effects in the pipe had subsided. It can also clearly be seen that, if the gates are opened again *quickly*, the velocity of the water entering the wheel will be decreased until the whole column acquires an increased motion; hence, the power applied will be diminished for a time instead of increased. These momentary and opposite effects make water government a harder problem to solve than the government of steam.

Third, water-wheel gates, as compared with steam valves, are heavy and unwieldy. They must also be moved through water, which is much denser than steam, hence cannot be moved with the same facility. They require much more power for *their movement*. Sometimes the designer of a water-power

plant does not place importance enough on the government of the wheels to make substantial gate rigging. The gate shafts may be too light, showing torsion when operating, or there may be a train of cog gears that allows much lost motion. The gates may be so designed that the water pressure gives them an unbalanced condition, requiring much pressure to be neutralized before it is possible to move them in a reliable manner. Turbine wheel gates built in this country often weigh several thousand pounds each, and sometimes must be moved several feet through water in being opened. Often it is necessary to add weight equal to their own weight as a counter-balance. The power required to overcome the inertia of and move this great mass often reaches many thousands of foot pounds. It can readily be seen that to govern such gates with precision and accuracy requires a combination of both delicate and powerful machinery. Also, when it is considered that it is possible to make the full change of an electric load in the fraction of a second and impossible for gravity to meet the power-demands short of a number of seconds, it is plain that to govern a water-power plant successfully is a matter of more moment than would seem at long range. It must also be borne in mind that the change of load must *occur*, and the speed must be *impaired* before it is possible for a governor to operate at all.

The fourth element to be considered is gravity, the source of all energy or power that can be had from water. Its effect can be considered as a constant in reasoning about power-getting. Of course, it is variable within certain limits. A square inch of opening at the bottom of a vertical column of water will allow gravity in a given time to generate a number of foot pounds of power, and in direct ratio to its height. This power is absorbed in giving velocity to a stream of water an inch square and spouting a number of feet per second. *Gravity has established an equilibrium in giving this velocity to the water.* If the opening were increased the power generated would increase in like ratio. It is the duty of the turbine wheel to reduce the velocity of this water as nearly as possible to zero without changing its own speed. In so doing the power is

transferred to the wheel shaft, where it can be carried to other points. With the exception of the small amount of power that is required to give a slow, downward movement to this vertical column of water, it can be said that the full effect of gravity is represented at the gate opening. Also, as soon as the opening is increased or diminished, there is practically the same increase or diminution in the amount of power represented by the volume and velocity of the water.

Again, if this column of water was extended in a horizontal direction from the top of the vertical column and the whole encased in a closed pipe or trunk, it can readily be seen that, when gravity operates on one square inch at the foot of the vertical column, it must put in motion the horizontal mass of water at the same time that it does the vertical mass. It is plain then that, while gravity has begun active operation as soon as the opening is made, its full effects will not be represented at the opening or wheel until the whole mass has been supplied with enough kinetic energy to give the necessary motion for the full spouting velocity at the gate opening. It is apparent that, while gravity is limited in the amount of power it can supply in a given time, it can be, and often is, further limited in its time of supplying power for governing purposes by the use of long pipes.

Considering the facts, that a change of load must be made before a governor can begin operating, that it requires time for a governor to perform its operation, that torsional and lost-motion effects are found in all gate riggings, that gravity must have time to do its work and may further be obstructed by injudicious flume construction, and that the wheel is limited to a certain opening and need not necessarily run in the ratio of the amount of water passing through it, it follows that absolute speed cannot be obtained in water-powers under heavy changes in load, as a change in load must necessarily change the speed before it is possible for gravity to furnish an increase in the supply of power. If there were no other factors government would be an impossibility, as a change of 50 per cent. in load would instantly cause a change of 50 per cent. in speed. But there *are* other factors, and, be it said to the credit of the



great engineers who designed America's greatest water-power plant, these other factors were clearly understood, intelligently calculated and incorporated into its construction. They are visibly stamped in every part of its make-up. (*Plate II.*) The first notable element is the size of the power units, 5,000 horse-power each. The second is the capacity of each unit for a storage of kinetic energy. It is absolutely necessary to have an accumulation of energy in reserve to tide over sudden fluctua-

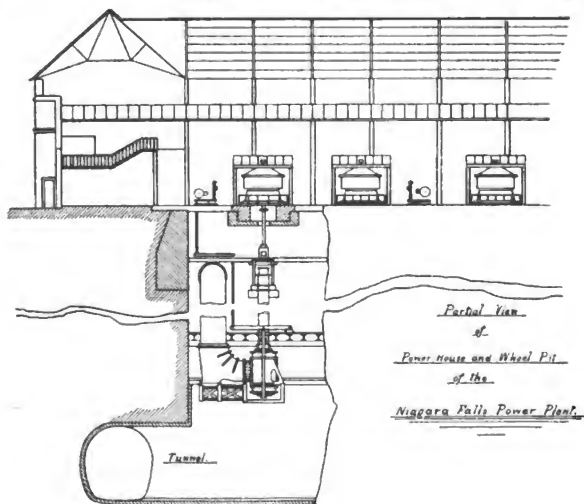


PLATE II.

tions in load until gravity can make proper compensation. The designers of the great Niagara plant first determined the degree of government necessary or desirable, and from this as a basis the plant was constructed. The results show that the speed government is well within the limits for which the units of power were designed. It is evident that there is a great accumulation of energy in reserve when an instantaneous change in load of 1,000 horse-power causes only 2 per cent. variation in speed, especially when the conditions are such

that it requires about three seconds of time for gravity to increase the power-supply to this amount.

There are several methods by which a reserve storage capacity can be maintained, but the one used at Niagara seems to be the simplest and most reliable. It certainly is the cheapest, being also purely mechanical. Reference is now being made to the balance-wheel or momentum effects of the revolving parts. It will be remembered that the armature, which is usually the lightest portion of a dynamo, is stationary in the Niagara Falls plant, while the field magnets, supported by an

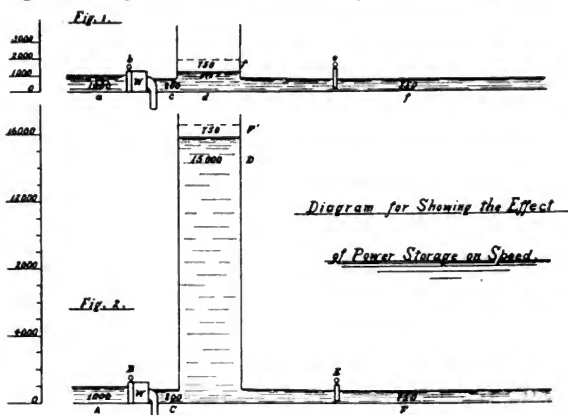


PLATE III.

immense steel band, are the moving parts. It is also noticeable that the great shafts reaching downward to the turbines are of large diameter, being great tubes. This is for the purpose of giving high velocity to as much of the material as possible. A certain capacity for stored energy was necessary for good government, and it is safe to say that if this could not have been reached with the present weights and velocities of parts, more would have been added in the form of actual balance wheels.

*Plate III* will serve to make clear the effects of power-storage in the government of a water-power unit.

In *Fig. 1* let *a* represent the power supply, *b* the water-wheel gate, *w* the wheel, *c* the turbine power, *d* the power storage, *e* the means of changing the load, and *f* the dynamos' power. It will be noticed that full 750 horse-power can be dropped off instantly by closing means *e*. The governor must operate at *b*, and it is safe to say that it cannot be in active operation before one second has elapsed. Note the condition at the end of the first second after the 750 horse-power was dropped. When *e* was closed there was only one outlet for the power generated at *w*, and that was to increase stored energy *d* to dotted line *f'* during the second. This increase will theoretically raise the speed of the whole plant 100 per cent. If it were not for some other principles that step in, this would be the actual speed at the end of the first second. In like manner, if the plant was running empty at normal speed, and 750 horse-power of load were added instantly, the plant would theoretically be standing still at the middle of the first second. Here also other principles step in and change this result somewhat.

In *Fig. 2* let *A* be the power-supply, *B* the water-wheel gate, *W* the wheel, *C* the turbine power, *D* the power storage, *E* the means of changing the load, and *F* the dynamos' power. Please note that all the conditions are the same, except that there is 15,000 horse-power of stored energy in *Fig. 2*, while there is only 375 horse-power in *Fig. 1*.

If *E* is closed, 750 horse-power will be dropped off, and finds a place at *F'*, increasing the volume of *D* 5 per cent., hence will theoretically increase the speed of power unit about  $2\frac{1}{2}$  per cent. by the end of the first second. This is also lessened somewhat by the same principles that affect *Fig. 1*.

It can readily be seen that here is a means of preventing extreme changes in speed until gravity can perform its part of the work. Note the conditions in *Fig. 2* if running at speed and a load of 750 horse-power were added. If the load were suddenly added it must be carried from the reserve power at *D*, using 5 per cent. of it during the first second, hence reducing the speed about  $2\frac{1}{2}$  per cent. theoretically. It can readily be seen that the speed will continue to drop until balanced

by new power generated at *W* after the governor has opened gate *B*. It can now easily be seen that *D* in any power plant can be increased until full change in load can be made with very narrow fluctuations in speed. In other words, every foot-pound of power or change in load can be intelligently provided for in the construction of a power plant, and variations in speed can be calculated for any change in load if the other conditions are known.

TABLE I.  
POWER STORAGE OF SOME WELL-KNOWN PLANTS.

Name.	Units of H. P.	Power Storage Capacity in H. P. for 1 sec.	Ratio of Power to P. S.
Niagara Falls P. Co. . . . .	5,000	50,000	1 to 10
Sacramento L. & P. Co. . . . .	1,000	8,000	1 to 8
San Joaquin E. Co. . . . .	450	9,000	1 to 20
Portland G. E. Co. . . . .	600	3,000	1 to 5
Niagara Falls Paper Co. . . . .	1,200	400	1 to $\frac{1}{2}$

*Table I* will serve to give an idea how the power units of plants differ in the ratio of their power to their power-storage. It is safe to say that if the other conditions were equal the possible government in their speeds would show equally as great a difference. Space forbids any further comment, except that each plant is desirous of good government.

TABLE II.  
APPROXIMATE LENGTH OF FEED PIPES IN EXISTING PLANTS.

Place.	Head.	Pipe.	
Ithaca . . . . .	94'	600'	Ithaca Pipe contains 737,500 $MV^2 = 11,800,000$ = 338 H. P. of kinetic energy in in pipe.
Great Falls . . . . .	40'	400'	
Spokane . . . . .	60'	600'	
Brantford . . . . .	30'	210'	
Fresno . . . . .	1410'	3800'	
Niagara Falls . . . . .	145'	200'	

*Table II* is intended to show the horizontal lengths of feeder pipes of some of the existing electric water-power plants.

It is unnecessary to go into the details of the calculations, but the purpose is to show the possible effects of momentum if the water-flow was stopped as quickly as an electric load is sometimes dropped. Taking the first in the list, that of the Ithaca Street Railway Company, it is found that the pipe holds 737,500 pounds of water. Assuming that this column

has a maximum velocity of 4 feet per second at full load, there will be a pressure of 11,800,000 pounds, or over 4,000 pounds per square inch at the water-wheel end of the pipe if the gates were closed as quickly as the load is dropped off. Since the static pressure is less than 50 pounds per square inch, and only a reasonable factor of safety provided, it is evident that a serious wreck would be the result of such a quick closing of gates. Yet such is necessary, theoretically, if even speed is desired.

It is also noticed that there is in this pipe before closing the gates 338 horse-power of kinetic energy for 1 second. Some disposition must be made of this energy, as it is necessary that the column of water be at rest when the wheel gates are closed. The only available disposition of it is to allow it to join the power set free when the load is dropped off, increasing its effect a like amount until the wheel gates can be safely closed.

It can now readily be seen that it is not only necessary to provide power-storage capacity enough in a power unit for the changes of load, but also an additional capacity for that contained in the pipes or flumes. This extra power must be provided on opening the gates before the wheel will furnish new power, and must be disposed of before the wheel will stop furnishing power when the gates are being closed. In other words, if the power unit in question is 900 horse-power, and calculations were being made to provide power storage so as to allow a full change of load to be made, keeping the speed inside of a given per cent., the calculations must be based on 900 horse-power plus 338 horse-power or 1,238 horse-power change at the whole gates. This makes it clear that closed pipes should be avoided as much as possible, if the government is to be done by changing the flow of the water. If it is desired to govern by deflecting the stream in some manner, the only detrimental effect of the long pipe is the power lost or gained by the varying friction in changes of load.

*Plate IV* is intended to show the conditions of speed on a 2,100 horse-power plant when 1,000 horse-power of load is instantly added. The kinetic energy in the pipe at full load is 1,000 horse-power for one second. The power storage of the

plant is 50,000 horse-power for one second. Assuming that the speed of plant is at normal or zero line until it reaches vertical time line marked zero, where 1,000 horse-power of load is instantly thrown on. This being 2 per cent. of the power storage, would cause a drop in speed of about 1 per cent. during the first second after the change. If no power were added, the speed would drop a trifle more than 1 per cent. during the second second, and continue to drop at an increasing ratio as the velocity of the revolving parts decreased. The curve indicated by the ciphers will show how the speed will drop during the following seconds if no new power were added to the wheel. Since it will require seven seconds to move the gates, the ratio of additional power-supply will be 300 horse-power per second, with a maximum action of the governor. Since

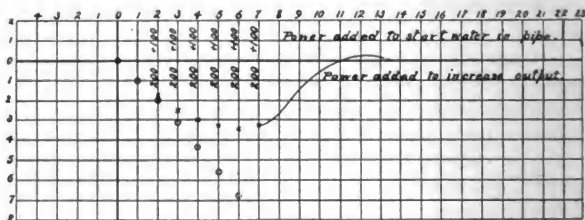


PLATE IV.

the increase in load is 1,000 horse-power, and 500 horse-power additional of kinetic energy must appear in the pipe, it will take the governor five seconds to add power enough to stop the speed dropping. Also, since the kinetic energy must be added to the flume in the same ratio that the new power is available, it is plain that only two-thirds of the 300 horse-power added each second is available as additional power while the velocity of water in the pipe is being increased. Hence only 200 horse-power is added as increased output for each of the following five seconds. This curve is indicated by the crosses at the ends of the several seconds. It can be readily understood that fully one second will elapse before any power-supply can affect the speed of plant. It can also readily be seen that the power storage must carry the 1,000 horse-

power new load for first second. While 200 horse-power has been added during the second second, it has performed an average of 100 horse-power work during this time. The power storage then has carried 900 horse-power of the new load during the second second. Since the full 200 horse-power is being added each second, the power storage is being gradually relieved of its drain and the speed stops dropping accordingly. A calculation at the end of each second shows exactly where the speed is at such time. Space will not admit the figures here, but the curve outlined by the crosses is approximately correct.

It is now evident that a formula can be deduced that can be relied upon in the government of water-powers. It will be somewhat complex on account of the many factors that must necessarily enter into it. Many of these factors will necessarily be fixed by the conditions that attend the plant construction. The size of the power unit will always be decided upon first. Next will be the maximum change in load, with the greatest variation in speed permissible. The time of change in power-supply is dependent upon the action of gravity and the safety of the plant. When the time required to supply power for the change of load has been learned, it is an easy matter to calculate the amount of stored energy or power storage that must exist in the plant in order to keep the variation of speed within the required limits. It will not be necessary to explain the fact that the speed will vary a fraction less in dropping off a load than it will in adding it.

In reducing the formula to its simplest form it will be necessary to combine or add together quantities that are of the same denominations, as follows: The time necessary to add power to overcome the increased friction in penstock, plus the time necessary to add power to overcome the inertia of the increased flow, plus the time necessary to add power for the new load, may be represented by  $T$ . The power necessary to equalize the increased friction, plus the power necessary to overcome the inertia in giving increased velocity to the supply, plus the power necessary to carry the increased load at speed, may be represented by  $L$ . The variation allowable in

speed in terms that are a fractional part of normal speed may be represented by  $F$ , and the power storage may be represented by  $S$ . Since the power storage must carry the new load for one-half of  $T$ , and since the speed of plant varies in one-half of the ratio that the stored energy is given out or absorbed, it is evident that the formula must read:

$$\frac{\frac{T L}{2}}{2 F} = S$$

Further reduction makes it read:

$$\frac{T L}{4 F} = S$$

The following example will make its use understood:\*

In the formula let  $T$  represent four seconds,  $L$  1,500 horse-power, and  $F$  3 per cent., or  $\frac{3}{100}$  variation of speed allowable. In making substitution and reducing, the stored energy or power storage in the power unit must be 50,000 horse-power. This is the amount necessary if 1,500 horse-power is to be added, and it requires four seconds to get the proper effect from the power-supply, providing the variation in speed must not be over 3 per cent. from normal.

Before closing it will be necessary to make a few suggestions concerning governors. A properly-constructed governor must open the water-wheel gates as fast as gravity can follow up with water, no faster. It must close the gates slow enough to insure safety to the penstocks, no faster. It must be capable of stopping the gates at any degree of opening. It must be endowed with the relay principle, adjusted to co-

\* In the formula  $\frac{T L}{4 F} = S$

Let  $T = 4$  seconds

$L = 1,500$  H. P.

$F = 3$  per cent. or  $\frac{3}{100}$  variation in speed.

By substitution we have

$$\begin{aligned} \frac{4}{4} \times \frac{1500}{\frac{3}{100}} &= \frac{6000}{\frac{3}{100}} \\ &= 50,000 \text{ H. P.} = S. \end{aligned}$$



operate properly with the power storage. It must *not* be a separate and independent feature of the power plant, but must be made a part of the plant in an intelligent manner, and at best it is only one of the factors in the government of a water-power plant. It must be remembered that all the governor can do is to open or close the gates as the variations in speed require, and no water-wheel can be governed successfully by varying the gate-openings unless the same principles are adhered to that make government in steam engines a success.

The *relay* principle allows the governed motor to run at a slower speed when loaded than when running empty. This is for the purpose of using systematically the stored energy of the revolving parts of the power unit. Recently a new feature,

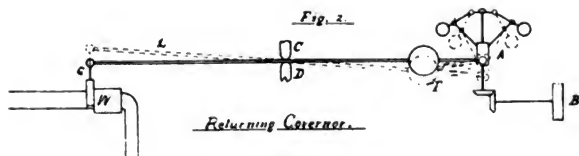
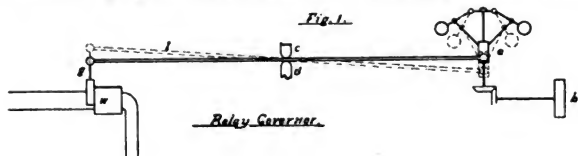


PLATE V.

generally known as the *returning* principle, has been added to some of the best-known governors. Both the *relay* and *returning* features will be shown in *Plate V*.

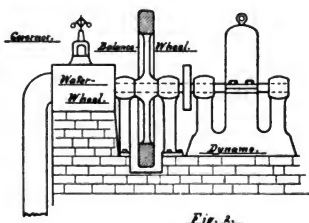
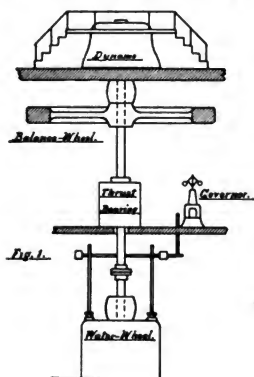
It is well understood that water-wheel gates are too ponderous to be moved directly by the centrifugal effect of governor pendulums. It is necessary to allow the speed governor to trip some heavier mechanical apparatus which moves the heavy gates. In some governors the pendulums throw into action an auxiliary power that in turn trips the apparatus that moves the gates. In *Fig. 1*, *a* is a speedy governor, *b* its pulley

that receives motive power from the water-wheel shaft,  $c$  is a trip to cause the heavy apparatus to close the gate,  $d$  is a trip to cause the mechanism to open the gate,  $w$  is the wheel,  $g$  is the wheel-gate, and  $l$  is a connection between gate and speed governor. (For the sake of convenience in the illustration  $l$  is a straight lever.) When the lever is so held by the governor balls that it touches neither  $c$  nor  $d$ , the gates do not move. If a change in load causes the speed to drop, the governor balls will allow  $l$  to touch  $d$ , and immediately cause the power mechanism to begin to open the gate. The gate in opening will raise  $l$  off of  $d$ , as is shown in dotted lines, causing the gate-moving apparatus to drop out of action. If this operation did not add new power enough to prevent the speed from a further drop, the same operation is repeated until the new power balances the demand and  $l$  touches neither  $c$  nor  $d$ . It will be noticed that the governor balls are running at a lower position after the gate has been moved to a wider opening. In practice this is a fact, and in this lowering of the speed a portion of the stored energy of the plant is fed out and used in carrying the new load, until the effects from the increased gate-opening can be had. If the power storage of the plant is proportioned properly to the change made in load, the speed can never fall out of the relay limits of the governor. But if the power storage is deficient, the speed on making a heavy change in load will quickly drop out of the relay limits, and the governor will then be at sea. The effect is called *hunting* or *racing* by engineers. (Let it be understood that an increase in speed will cause  $l$  to touch  $c$ , and close the gates in a similar manner.

*Fig. 2* is similar to *Fig. 1*, with the exception that  $L$  is flexible or jointed at  $E$ . In a change of load  $L$  operates as a stiff lever, but after the equilibrium has been temporarily restored the lever  $L$  slowly begins to bend at  $E$ , allowing  $A$  to return to its original position. This bending or returning will cause  $L$  to touch  $D$  and add a little more water, until  $A$  has found its original position or speed, as is shown by dotted lines. It will be noticed that the power storage in *Fig. 2* is made use of in adding new load, by lowering the speed in the same man-

ner as in *Fig. 1*. But this defect is corrected later by the *returning* principle. The effect of the returning principle is to return the speed always to normal, leaving it identical with the speed at no load, a condition not ordinarily found in speed government where the relay governor is used.

Let it be understood that all steam engines that are successfully governed are controlled by the use of a relay governor, although it is not apparent to the casual observer. Some of our best steam engines use the returning principle in connection with their governing, although no reference is



General Design of Plant Constructions  
that are Favorable to Government.

PLATE VI.

made to it in ordinary conversation concerning steam-engine government.

The science of water-power government has not yet reached so great a degree of perfection as the government of steam power, yet the underlying principles are being carefully studied by our engineers, and the time is not far distant when our water-powers will all be constructed and governed as reliably and successfully as our steam plants are, but that time will not come until the same principles are recognized in the former as in the latter. (*Plate VI.*)

## Mining and Metallurgical Section.

[*Stated Meeting, October 13, 1897.*]

MR. BENJAMIN SMITH LYMAN, President, in the chair.

### RECENT DEVELOPMENTS IN THE MANUFACTURE AND APPLICATIONS OF WIRE-GLASS.

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BY FRANCIS SCHUMANN.

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Having been requested to bring before you any facts and information bearing upon recent developments in the manufacture and application of wire-glass, and being closely identified with the industry and occupied in observing its characteristics, I am enabled to present to you the following data:

Wire-glass, first suggested as early as 1854, differs from ordinary glass only in that a sheet of wire netting is inserted in the middle of the glass sheet while in process of being rolled into plates or sheets, and while the glass is yet in a plastic state. The addition of the wire netting when successfully inserted does not affect either the strength or ductility of the glass to any appreciable extent, but does most effectively prevent disintegration or separation of the sheet after fracture, whether from impact or heat.

It is now and for several years has been manufactured to a considerable extent in the United States, England, and Belgium, and to a less extent in Germany and France. Its principal uses are for skylights, windows and partitions. It is also extensively used as a substitute for iron fire-proof shutters, because it admits light and greatly excels in its fire-resisting qualities.

Wire-glass is made in sheets one-quarter inch thick, and of any size and shape, the maximum size of sheets being 30 inches wide by 120 inches long.

Its fire-proof qualities are extraordinary but will readily be explained if the non-conducting power of glass be considered; thus, sheets of glass set in wooden frames covered with some non-combustible material, such as asbestos cloth or ordinary tin, remained in position and prevented the passage of flames

or hot gases, although subject to a heat on one side sufficiently great to fuse the surface of red brick. The first action of the heat was to expand and bulge the glass, and also to cause cracks. As the heat intensified, the exposed side of the glass partly fused or became plastic, but never beyond a certain degree, no doubt due to the dissipation of heat from the opposite side, which was exposed to the ambient normal air, and which prevented the temperature from reaching a point that would completely melt the glass.

The wire netting, woven of No. 22 B W G wire, having hexagonal meshes about 1 inch across, is not affected by the atmospheric moisture or other corrosive agents, except to a slight degree at the edges of the glass where the ends of the wire are exposed, the imbedding of the wire within the glass proving an absolute protection.

The resistance of wire-glass to breaking does not vary from that of glass of the same thickness without the netting, because the netting lies within the neutral axis of the sheet when considered as a beam subject to a transverse load, nor is the ductility affected, provided care be taken to attain homogeneity when inserting the netting, and also in applying the proper treatment in annealing. This operation causes the greatest difficulty, in that it depends on the application of a certain temperature at a certain stage, and, because of the well-known lack of measuring appliances or instruments, the hitting of the right conditions is largely dependent upon a personal equation. Hence it is that the breakage in one order will be practically *nil*, while in another it may reach an appreciable percentage, although both lots have been made by the same persons with the same methods and with the same care.

Defective annealing causes initial stresses in the sheet of glass, which, unfortunately, do not manifest themselves, no matter how carefully the glass may be examined, until after the glass is set in position and exposed to the elements, notwithstanding the strains it was subjected to when cutting to size or concussions during transportation or handling previous to being placed in position in a skylight. Acquired experience and knowledge are of course lessening these difficulties and gradually removing them.

It has been asserted that failure of wire-glass would finally result by reason of the difference of expansion between the glass and the iron or steel composing the imbedded wire netting. That such is not the case is readily proven. The rate of expansion (or contraction) of iron or steel is about one-third greater than that of glass. This very fact makes wire-glass a possibility, and for the following reasons: The wire netting, when being inserted into the hot and plastic glass, because of its power of rapidly conducting heat, quickly attains the temperature of the glass, and, in consequence, its maximum degree of expansion, the volume of wire being inappreciable compared to that of the glass. The glass being still plastic clings to the expanded wire, but, as cooling proceeds and contraction ensues, it gradually shrinks from the glass, leaving, when entirely cooled, an annular space between it and the glass, and hence no possible strain can come upon the glass from any future variations of temperature which may arise in service.

As to the effect from variations longitudinally, it will be found that the strength of the glass in sheets one-quarter inch thick is so greatly in excess of the ultimate tensile resistance of the wire as to cause it to tear without the slightest effect upon the glass, were it possible to bring the ultimate stress upon the wire. That the wire in the glass is under tension is of course a consequence, and a most desirable result, as experience has shown, in that it tends to closely unite the glass when cracked, and thus prevents leakage from rain; this trait has often been observed and noted, and has been a reason for the retention of sheets in skylights which otherwise would have been removed.

As to the passage of light, recent tests have shown that ribbed wire-glass diffuses more light throughout a building than ordinary glass, the greater efficiency being of course due to the effect of the ribbing.

Wire-glass can be bent or curved into any form. The operation, however, is expensive, requiring special forms or moulds, and its use is consequently avoided as much as possible.

In wire-glass the architect and engineer has an article of undoubted value in the light of modern requirements. A

medium for enclosing space, fire-proof and water-proof, transmitting light, not liable to disintegration by corrosion or combustion, and difficult of penetration, which still maintains its utility, no matter how much it is subdivided by cracks, as it will neither leak nor fall apart and injure those below when used in skylights.

I have here a sample of wire-glass, 1 foot square, cut from a large sheet. The piece was reheated to almost fusion (about 1,200° Fahrenheit), then suddenly immersed to half its width in cold water. You will notice that the piece is yet intact and complete, suitable for any purpose for which it was originally intended.

Here, again, is another sample, showing the mode of decoration when used for partitions or screens; while this third sample is a piece of so-called "rough-ribbed wire-glass," much used for skylights and windows, the ribbing greatly adding to the diffusion of light.

Within the past year the principal manufacturers in the United States, England and Belgium have greatly enlarged their plants for its manufacture, and are making such rapid strides in perfecting the methods of manufacture that it will not be long before wire-glass will be generally accepted as an established commercial product, its process of evolution being analogous to that of steel.

In conclusion, I will exhibit several lantern slides illustrating the action of heat upon the glass, as also a view of a skylight roof, from below, of a large structure in this country, which will permit of a comparison of wire-glass with ordinary skylight-glass.

*Figs. 1 to 8* illustrate a test of the fire-resisting qualities of wire-glass, made under the supervision of Secretary Chas. A. Hexamer and Inspector Wm. McDevitt, of the Philadelphia Fire Underwriters' Association, on April the 30th, 1896.\*

\* The brick test-house referred to in accompanying series of views, was built of 9-inch walls, measuring 3' x 4' x 9', interiorly. Iron grate-bars were placed about 2 inches above the ground level, immediately above the cross-shaped openings arranged to supply air for combustion. The top of the test-house was roofed with a skylight, one side with  $\frac{1}{4}$ -inch wire-glass, and the other with  $\frac{1}{4}$ -inch rough-rolled skylight glass of the ordinary kind. The

*Fig. 1* shows the test-house immediately after lighting the fire and closing the door.

*Fig. 2* is a view taken two minutes after lighting the fire. The smoke had blackened the glass of the door and cracked the glass in the window. The half of skylight glazed with  $\frac{1}{4}$ -inch wire-glass is on the same side as the window, and shows in this picture.

*Fig. 3* is a view taken three minutes after starting fire. The heat is sufficient to warp the wire-glass. The plain glass on the other side of the skylight had just commenced to break and fall.

*Fig. 4* shows the condition of things fifteen minutes after starting fire. There is evidence of considerable increase in the intensity of the heat, and evident charring of the wood in the frame and door incased in tin.

*Fig. 5.*—Fire twenty-five minutes under way. Wire-glass in door and window at a red heat, sufficient to cause the glass to buckle. This buckling was due largely to portions of the firewood pressing against it while in this plastic condition.

*Fig. 6.*—Fire thirty-five minutes under way. This view shows the side of skylights, glazed with ordinary glass, which had fallen in five minutes after the fire had started. The portions of glass still remaining were protected from direct heat by the thickness of the brick walls immediately underneath, which also prevented them from falling.

*Fig. 7* is a view taken after water had been thrown on the skylight while the fire was at its greatest intensity. The walls had cracked, and the plain glass was partly melted, as is seen in the opening at the opposite side of the building. The wire-glass in the window below, owing to the absence of clips, had curved outward at the top. The door was still intact and in position.

*Fig. 8* is a view taken after the fire had been extinguished and water had been thrown on the glass with a hose. All of the wire-glass was intact. The panel of the door is seen with the tin covering ripped off, showing the charred condition of the wood inside, but which still retained its form.

*Fig. 9* is a photograph of the ruins of two factory buildings at Newark, N. J. One was a five-story and the other a one-story building, separated by an alley 4 feet 8 inches wide. The one-story building contained eight windows, furnished with wire-glass, set in angle-iron frames, in place of iron shutters. The view shows one of these windows after the fire, which caused the fall of the smokestacks of the large building and the destruction of all of the small building; a portion left standing containing the window.

frame of skylight and the sash-bars were of wood covered with tin, both being glazed with wire-glass held in place by iron clips. A window of  $\frac{1}{4}$ -inch thick wire-glass, with iron frame, was set in one side of the house, and the wooden door, with an upper panel of  $\frac{1}{4}$ -inch wire-glass, was tin-lined. The tin covering the woodwork has lock seams.

A quarter of a cord of wood, thoroughly saturated with oil and mixed with resin, was placed on the grate-bars ready for lighting.





FIG. 1.—Test-house at starting fire.



FIG. 2.—Two minutes after lighting fire.



FIG. 3.—After three minutes.



FIG. 4.—After fifteen minutes.



FIG. 5.—After twenty-five minutes.



FIG. 6.—After thirty-five minutes.



FIG. 7.—After water had been thrown on skylight. Fire at greatest intensity.



FIG. 8.—Test-house at close of experiment.

*Fig. 10* is an interior view, looking up towards the roof, of a large train shed of a railroad station in one of the large cities of this country. The photograph was taken a few days after a severe March snow storm.

The upper part of the roof was glazed with ordinary skylight-glass, while the lower portion was wire-glass. How the

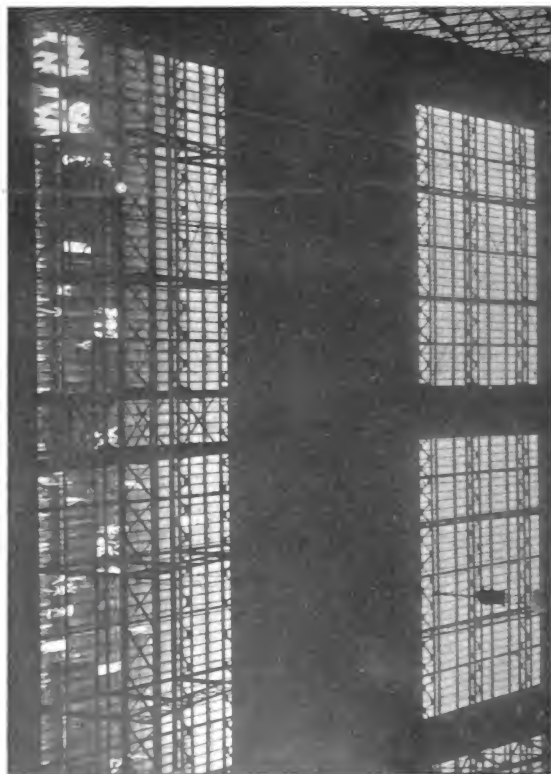


*Fig. 9*—Wire-glass window in building of Newark Stamping Company, after fire.

storm affected the ordinary glass will be noticed by the number of broken sheets. The opacity of this part of the section of the skylight is caused by the soot clinging to the glass, the safety wire netting stretched beneath interfering with the proper cleaning of the glass.

While many of the wire-glass sheets were cracked by the

storm, none of them were displaced, and they remain in place to this day. Attention is also called to the bright appearance of the wire-glass section, which denotes its clean condition. This



*Fig. 10—View of skylight in train-shed, Pennsylvania Railroad, Broad Street Station, Philadelphia, after snow storm, March 16, 1895. Upper section, ordinary skylight glass. Lower section, wire-glass.*

is due to the fact that it requires no protecting shield of wire below, which is necessary with ordinary roof lights, and hence interposes no difficulty in cleaning.

## THE FRANKLIN INSTITUTE.

*Stated meetings, September 15 and October 20, 1897.*

MR. JOHN BIRKINBINE, President, in the chair.

### THE SMOKE NUISANCE AND ITS REGULATION, WITH ESPECIAL REFERENCE TO THE CONDITION PRE- VAILING IN PHILADELPHIA—IMPROVED FUR- NACES AND MECHANICAL STOKERS.

*(Concluded from vol. cxlv, p. 24.)*

#### THE BLACK DIAMOND SMOKELESS FURNACE.\*

THE SECRETARY:—The accompanying illustrations show the design and construction of a smokeless furnace containing all the necessary elements for smokeless combustion and high economy. The simplicity of construction is shown in several illustrations, where it will be seen that the practical operation of the furnace for high efficiency and smokeless combustion is comprised in the method of providing highly-heated surfaces of ample dimensions to maintain the requisite temperature for complete combustion and the provision that it is made for the introduction of a suitable quantity of air to supply such combustion at the proper time and only so long as required.

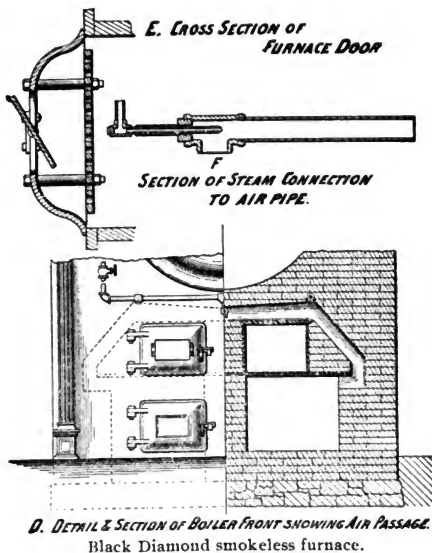
The bridge wall in this furnace is made to conform to the shape of the boiler for a portion of its height, leaving sufficient space between bridge wall and boiler for passage of the gases, while the main portion of the gases and products of combustion find free outlet through several arched openings in the lower portion of the wall.

An essential feature is placing the arched portion of the bridge wall back some distance from the grates, to provide an opportunity for the proper mingling of the air and gases and permitting time for combustion to take place before they pass the bridge wall. This is an important feature, for, in ordinary furnaces, sufficient time is not given for the mingling of air and gases before passing the bridge wall, where they come in contact with the cooler boiler-plate, thereby having their temperature reduced below the combining point, so that air

\* Manufactured by Bowe & Co., Chicago.

and gases mixed, but uncombined, pass off unconsumed, carrying away a large number of heat units that might be utilized by proper arrangement of furnace, such as is here provided.

The temperature required for the complete combustion of the gases of coal with air is known to be  $800^{\circ}$  and upwards, while the temperature of boiler at the highest steam pressure is less than one-half the ignition point of coal and less than

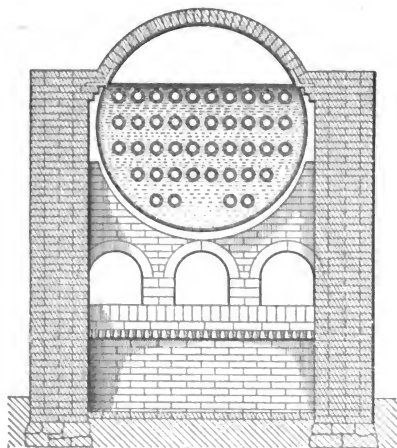


one-third the temperature of complete combustion, so that in furnaces as ordinarily constructed a large amount of heat-making matter is wasted. In the method adopted in this furnace the products of combustion are compelled to pass through the brick flues in the bridge wall, which are always at red heat, a temperature sufficiently high to provide for complete combustion. This temperature being secured, the gases combine with the development of a greater heat and provide

a temperature at which soot, as such, cannot exist, consequently cannot be produced.

The attention necessary with this combination is so slight as to give no inconvenience to the fireman, as the results are obtained automatically after the apparatus is once adjusted to the kind of fuel used and the amount burned. Any change in kind or amount of fuel necessitates but slight and easily-made adjustment of the automatic device.

That part back of the bridge wall, commonly called the

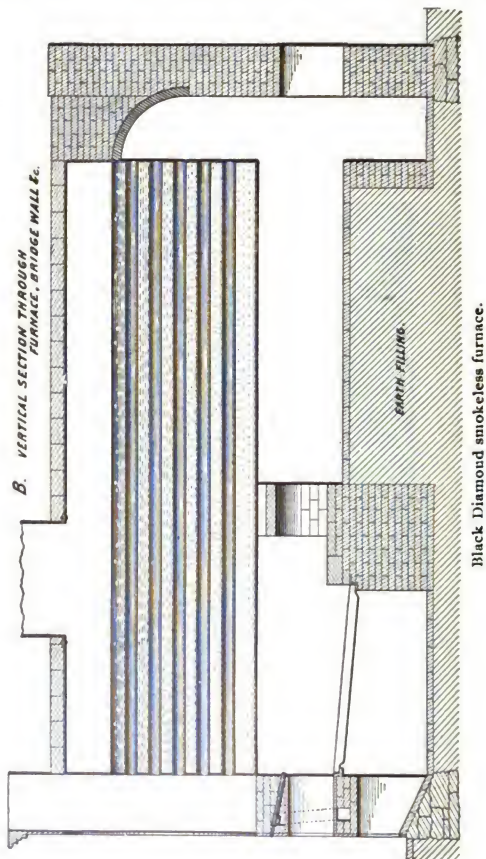


*C. CROSS SECTION THROUGH FURNACE IN FRONT OF BRIDGE WALL,  
Black Diamond smokeless furnace.*

combustion chamber, is partially filled with earth and paved with fire-brick, forming a flame bed, which is always maintained at a high temperature, thus assisting in the complete combustion of any uncombined air and gases which may have passed the bridge wall. By this arrangement the gases entering the tubes at the back end are of a temperature due to the complete combustion of the fuel, which is provided for by the heat radiated from the fire-brick paving. The temperature thus secured overcomes the necessity of a large combustion

chamber, in which the gases are given more time to thoroughly mix and combine, the heat in this case greatly reducing the time necessary for the combustion to take place.

The arch and other highly heated surfaces providing the





proper temperature, the air supply for complete combustion is obtained through the panel door and baffle plates shown in the front view of boiler. The door is provided with a damper hinged at its center and controlled by the automatic device shown on the left. By this arrangement the air supply through the front begins as soon as the doors are closed, at the time when most air is needed, in order to provide for smokeless combustion. The automatic device gradually decreases the amount of air supplied, by slowly closing the dampers in the doors and shutting off the steam operating the steam jets, which are provided for use in case very rich coal is used, or the demand for steam requires strong firing. The air thus injected is drawn through a passage concealed in the brick-work, thus heating it to a high temperature before permitting it to mix with the gases.

The automatic regulation of the air supply is a most essential feature in the economical production of smokeless combustion.

Practice proves that suitable means for maintaining a high temperature of the air and gases must be provided in order that perfect combustion can take place. The bridge wall and flame bed lining provide this, as just explained. The arrangement of bridge wall, flame bed, etc., is shown in the vertical section through furnace and boiler and in the small cut showing cross-section through furnace in front of bridge wall.

It is claimed for this furnace that it is constructed on correct scientific principles, and that it will both burn smoke and consume any kind of coal without smoke, and with any kind of chimney draft, while it has been shown to yield very economical results. The furnace is simple in construction and durable. (From data furnished by the manufacturers.)

THE ACME MECHANICAL AUTOMATIC STOKER.\*

MR. WM. E. GRAY [New York]:—The theory of smoke prevention, as well as the theory of combustion, has been so thoroughly and ably presented in the previous discussion of

\* Manufactured by the Falls Rivet and Machine Co., Cayahoga Falls, O.

the smoke nuisance question, which has appeared in the *Journal*, that it will not be necessary for me to attempt to add anything to that phase of the subject.

The "Acme Stoker," which I have the pleasure of bringing to your notice, burns all grades of bituminous coal practically without smoke, and comes well within the limits of the strictest smoke ordinance. It is durable, economical, efficient and practical, and embodies in its construction several novel features.

An examination of *Figs. 1, 2, 3 and 4* will explain its mechanism and operation.

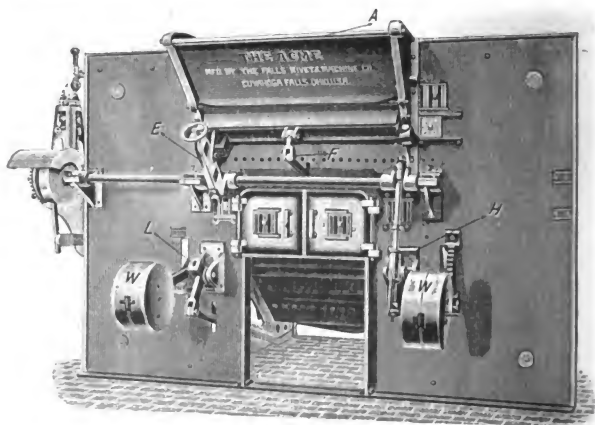


FIG. 1.—Boiler front equipped with Acme stoker.

In erecting the stoker in connection with any of the different types of boilers, the regular lower half of the front (as supplied for hand-firing) is replaced by a special cast-iron stoker front, as shown. In *Figs. 1 and 2* this front is shown with the grates in position for automatic stoking.

The stoker is operated by the small engine shown on the left-hand side. The hopper is filled with coal, which is pushed onto the dead-plate, C, and then down to the auxiliary

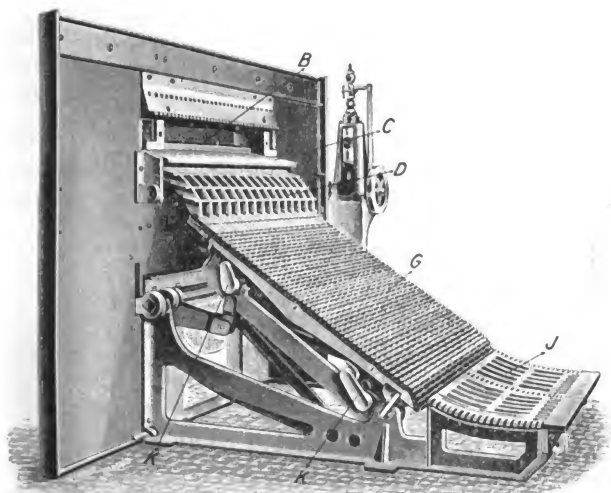


FIG. 2.—Acme stoker ; grates in position for automatic stoking.

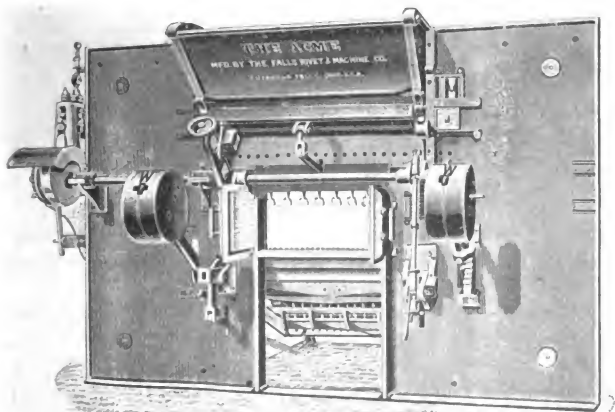


FIG. 3.—Acme stoker ; grates dropped for hand-firing.

grates, *D*, by the coal pusher, *B*, which is operated by the regulator at *E*—this being so arranged as to give any desired feed, from nothing up to the full capacity of the stoker. The auxiliary grates, *D*, are moved by the lever, *F*, and are controlled by *E*. The grates, *G*, are  $1\frac{1}{8}$  inches wide, each alternate one being movable, the remainder being fixed.

The alternate grates are moved by levers, *K K*, their motion being regulated at *H*. First, they are raised above the

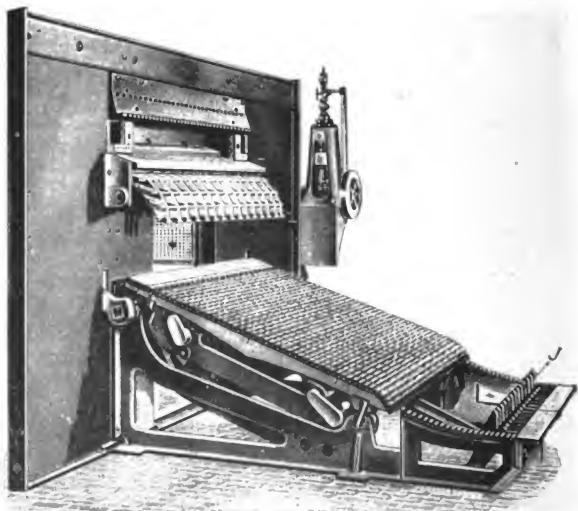


FIG. 2.—Acme stoker; grates dropped for hand-firing.

fixed grates and then moved forward, carrying the burning coal with them, afterwards dropping back to their original position.

The dumping grate is shown at *J*. *Fig. 2*, in position to receive the ash and clinker from the grates, *G*. This is controlled by the lever, *L*, and can be dropped, as shown in *Fig. 4*, to deposit the refuse in the ash-pit, which is then cleaned out in the ordinary way.

*Figs. 3 and 4* show the stoker with the grates dropped to a position where they can be fired by hand in the ordinary manner. *W W* are counterbalance weights to assist in raising and lowering the grates *G*. The grates can be shaken by hand from the front by means of *H*. By this means there is no danger of loss of boiler service on account of accident to the stoker mechanism, and it also makes every part as accessible as in a plain furnace. It also greatly facilitates the starting of the fires.

In regular operation the coal is filled into the hopper, *A*, and from there fed to the dead-plate, *C*, where the coking is commenced; from there it passes to the auxiliary grates, *D*, for the completion of the coking and the full ignition of all the coal and coke, which is greatly aided by the extra large air space at this point. It then passes to the grates, *G*, where, as it burns, it is gradually pushed down to the dumping grates, *J*, at which point nothing remains but ash, this being dropped into the ash-pit at regular intervals.

For the prevention of smoke and the complete combustion of the volatile matter in the coal, an inclined fire-brick arch is started over the auxiliary grates, *D*, and carried back towards the bridge wall.

Methods of construction and attachment vary with the different styles of boilers, but it will not be possible to describe them in this brief abstract.

The "Acme Stoker" is a thoroughly practical smoke preventer, and as such has been presented to this Institute, in response to the invitation of your Secretary.

THE COLUMBIA MECHANICAL STOKER AND SMOKELESS  
FURNACE.\*

MR. G. E. MANNING [Westfield, Mass.]:—This stoker is a simple and durable apparatus, which receives the fuel in bulk and feeds it mechanically at any desired rate to the furnace, and after consuming all combustible matter contained in the fuel, deposits the ash and clinkers in the ash-pit.

\* Manufactured by the Columbia Stoker Company, Holyoke, Mass.

There are two vital features of this stoker which should have special consideration:

(1) The grate is stationary; there are no moving parts exposed to the fire and likely to cause expensive repairs and shut-downs.

(2) The coal is fed *under* the burning fuel, and, all

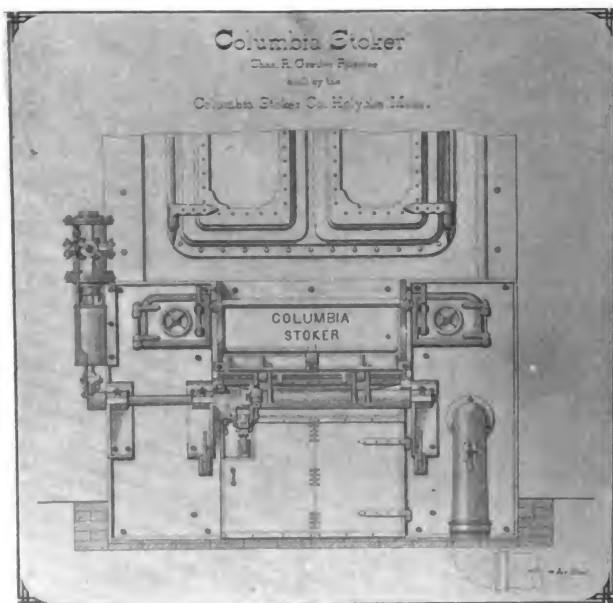


FIG. 1.—Front view of the Columbia stoker.

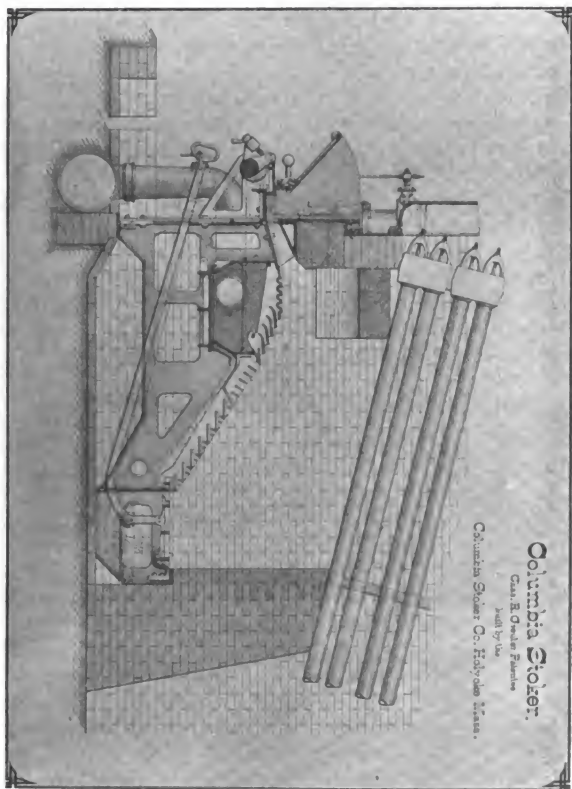
gases liberated therefrom being thoroughly mixed with the incoming air before passing through the incandescent bed of fire, a practically smokeless chimney is the result.

The operation of the "Columbia Stoker" is as follows:

Owing to the incline in the fuel passage, the fresh fuel will have a tendency to slide along the fuel plate directly on to the

blast grates, and in doing so, cause the bed of incandescent fuel, in course of combustion, to bulge or rise up; the heat from the burning fuel will slowly liberate the gas from the

FIG. 2.—Section through furnace (Columbia stoker).



incoming fresh coal, and the air forced through openings in the blast grates in passing up through the fresh fuel will be

thoroughly mixed with the gases liberated before passing through the burning fuel above, resulting in a bright, clear fire and the complete consumption of all combustible elements in the fuel. The incoming fuel (on account of being pushed up the incline) is in a compact mass, and will not permit cold air to pass into the furnace, as the whole of the grates is covered with an even layer of coal. This process of feeding in fresh coal, which raises or replaces the ignited fuel, is going on continuously, the resulting ash and clinkers being gradually forced over the top on to the inclined grates for final combustion, air being supplied through the openings in the grates induced by ordinary chimney draft. A drop or dump grate, provided for the removing of clinkers and ashes, is located on the lower end of the incline grates, and is operated by handle bars extended through the front of the furnace. The whole operation of removing the clinkers and ashes only requires a few minutes, and can be done without interfering with the regular course of firing. (Correspondence.)

DAVIES AUTOMATIC STOKER AND SMOKE CONSUMER.\*

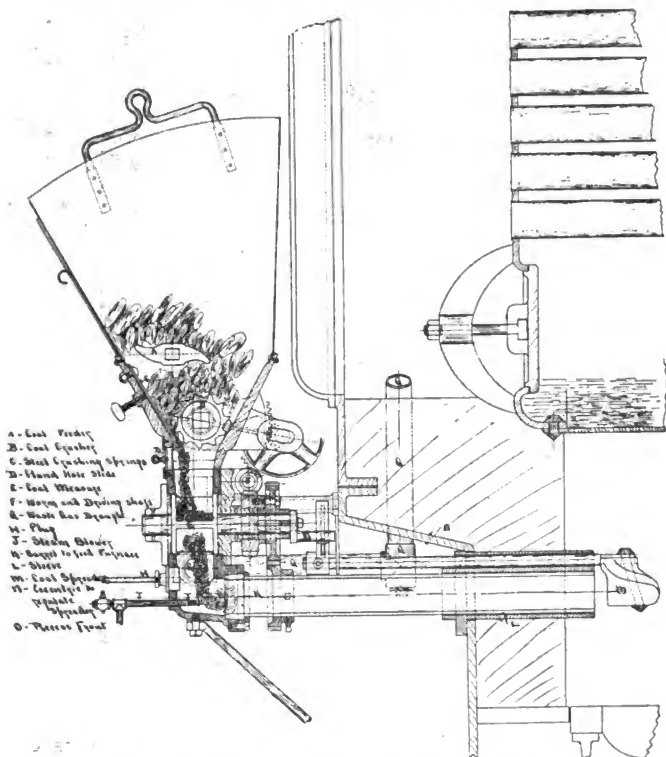
MR. A. T. EASTWICK [Bridgeport, Montgomery County, Pa.]:— \* \* \* The Davies Stoker Company has recently been organized for the purpose of introducing the Davies automatic stoker, which has been in operation for nearly a year, and has been thoroughly tested in regard to its efficiency in saving fuel and in increasing the boiler capacity. It has also proved to be very effective as a smoke consumer, but we wish to demonstrate more exactly its efficiency in this respect, and we are now equipping a Galloway boiler with this object specially in view, and we think we will soon be able to show more fully that our stoker will consume practically all the smoke from ordinary bituminous coal. In the meantime, we do not care to make any specific claims for the machine in this respect. We have no doubt, however, that it consumes most of the smoke, as the machines now in use show.

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\* Manufactured by the Davies Stoker Co., Bridgeport, Montgomery Co., Pa.



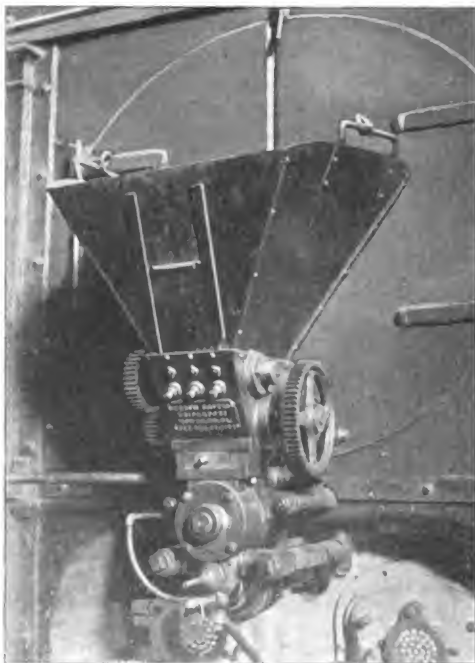
\* \* \* The appearance and construction of the machine is shown by accompanying cuts. It was constructed for the purpose of saving fuel and increasing the boiler capacity, but, as we have already stated, it has also proved to be a smoke consumer. For the purpose for which it was con-



Vertical section showing parts of Davies automatic stoker.

structed it is very successful, showing a saving of 10 to 15 per cent. in fuel over hand-firing, and increasing the boiler capacity from 15 to 25 per cent.

The stoker is so simple in construction, and so much less expensive than any other stoker we have seen, that we feel it only remains for us to demonstrate more thoroughly its smoke-consuming merits to compete successfully with the leading machines of its kind in the market.



Front view of Davies automatic stoker, attached to boiler.

The Davies automatic stoker can be applied to any make of boiler or furnace, and is attached by bolting to the front plate with two bolts and a brace from below. A 5-inch hole is cut through the front plate and brick arch above the fire-door, and 15 to 18 inches above the grate bars, through which

is inserted a sleeve for the revolving tube, which carries the fuel into the furnace. When attached to a marine or upright boiler a 6-inch hole is cut through the water space into the fire-box, and a 6-inch tube inserted and expanded, in order to admit the sleeve for the revolving tube. The two 2-inch pipes leading from the feeder into the smoke flue draw back the greater part of the smoke and waste gas, and return it for consumption with the fresh fuel into the furnace.

It feeds the fuel into the furnace in any size required, from chestnut size to a powder, and is especially adapted for the burning of soft coals of all kinds. In attaching the stoker no alteration of grate bars or fire-doors is necessary, and boilers can be fired in the ordinary way if necessary. The grate surface may be reduced 15 to 20 per cent., and more steam obtained with the stoker than by hand-firing. It is easy on the brickwork, and does away with heavy bars and pokers for shaking the fires.

The operation of the stoker is as follows: The coal is placed in the hopper, and is carried in uniform quantity in the furnace through the tube *K* by means of the fine steam jet after reaching blower *J*. The coal is spread evenly over the grate surface by means of the deflector *M*. The quantity of steam required is very small, being about one-fifteenth of 1 per cent. A steam jet also creates a suction through pipe *Q*, which passes along the sides of the furnace to the rear of boiler, thus furnishing an excess of heated air. (Correspondence.)

#### DISCUSSION.

##### THE ECONOMETER OF MR. MAX ARNDT, OF AIX LA CHAPELLE.

MR. ARTHUR FALKENAU contributed to the discussion a description of the instrument known as "The Econometer," illustrating his remarks by reference to a specimen of the apparatus and a sectional view of same projected on the screen.

The instrument is a gas balance, and is designed specially to act as a continuous indicator of the percentage of carbonic acid gas present in the products of combustion from a steam boiler furnace, thus affording the operative in charge of the

furnace a visible indication at all times of the condition of his furnace fires.

The econometer is said to be extensively used in Germany, where its value as a practical appliance for promoting the economical combustion of fuel in steam plants is generally recognized.

The following description of the construction and operative features of the apparatus (in lieu of Mr. Falkenau's remarks, which were not furnished for publication) is abstracted by the Secretary from a report thereon, lately adopted by the Committee on Science and the Arts:

Referring to the accompanying cut, the apparatus consists of a balance, carrying at one end a gas vessel provided with a neck open at the bottom; a gas delivery pipe projecting upward into this gas vessel, being fixed and supported in it in such a way that upon the oscillation of the balance beam the gas vessel may move freely up and down without coming in contact with the upward projecting pipe through which the gas flows into the gas vessel.

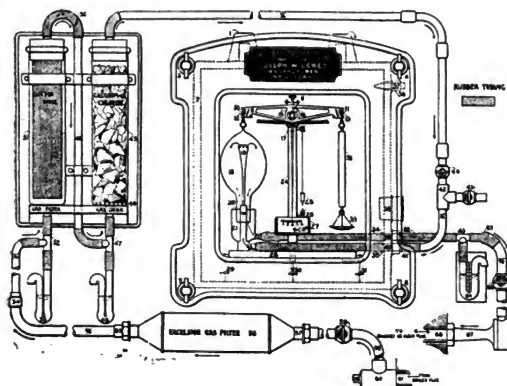
The gas vessel is balanced by a compensating vessel suspended from the opposite end of the beam, also open at the bottom, and equivalent to the gas vessel in its capacity in conjunction with small weights placed under a pan under the compensating vessel, that the pointer of the beam shall move to zero on the scale when atmospheric air is drawn through the apparatus.

The gas vessel being open at the bottom so that the pressure within it is always the same as that without, fluctuations of pressure and barometrical readings have not to be considered in the use of this apparatus; likewise fluctuations of temperature do not affect its action, because the gases passing slowly through the apparatus quickly take the temperature prevailing in the narrow gas passages.

The fluctuations which take place in the density of the gases round the fixed pipe in the gas vessel cause up-and-down motions in the latter vessel, which are shown by the pointer on the scale. This pointer is rigidly fixed to the beam so as to follow the movements of the gas balance; it oscillates in

front of a scale indicating units of weight by the distance between its dividing lines; or these distances shall, in conjunction with the pointer, indicate a particular percentage volume of a particular kind of gas in a gaseous mixture; for example, the instrument exhibited and described had divisions on its scale for indicating the percentage volume of carbonic acid gas for the purpose of ascertaining the percentage of such gas escaping in the products of combustion from a steam boiler furnace.

Two tubular orifices are provided, one for the inlet, and the other for the outlet, of gases, the former connecting by a



The Arndt "Economometer."

flexible tube with the vertical fixed pipe in the gas vessel, and the latter by a flexible tube with the cup-shaped vessel situated below the gas vessel. The source of the gas supply is placed in communication with inlet leading to the gas vessel and a suction apparatus of any suitable kind in communication with outlet from the cup vessel under the gas vessel. A portion of the air present in the casing is first drawn off, that is to say, the air is exhausted by suction to so much of a vacuum as corresponds to the strength of the suction at the cup vessel under the gas vessel. This rarefaction being obtained, the

gas to be weighed passes into the gas vessel, filling it, and then out of this vessel into cup vessel below.

The gas balance is enclosed in a casing provided with a glass front for the purpose of observation; this casing is provided with an aperture closable by a plug, upon the removal of which the weights may be adjusted as required. Further, at the top of the casing there is an aperture filled with cotton-wool for the gradual and continuous admission of atmospheric air thereto. The balance is, therefore, located in a nearly airtight chamber, with its several parts so arranged that, when the gases to be weighed flow through a vessel forming part of the balance, it may operate without resistance and with greatest sensitiveness.

The determination of the percentage volume of a particular kind of gas contained in a gaseous mixture is only practicable by means of the apparatus when the specific gravity of the gas sought for is different from the specific gravities of the other gases preponderating in the gaseous mixture, but such other gases may be of like specific gravity among themselves. This, for instance, is the case with respect to the smoke gases of steam generator furnaces, which gases are mainly made up of oxygen, nitrogen, carbonic oxide and carbonic acid. Of these, the first three are of nearly the same specific gravity, approximating that of atmospheric air = 1. On the other hand, the specific gravity of carbonic acid = 1.52, and is therefore about one-half heavier than atmospheric air, and a smoke gas mixture must consequently be heavier the greater its contents of carbonic acid.

With perfect combustion of the carbon contained in the fuel and with the air of combustion measured in a theoretically accurate manner, the carbonic acid of the smoke gases amounts to about 20 per cent. of the total volume, but it is less than this when the air of combustion is supplied in a larger quantity. If now the zero line of the scale has such a position that it coincides with the pointer when only atmospheric air is present in the gas vessel; if, further, the end line or division of the scale has such a position that it coincides with the pointer when atmospheric air, mixed with carbonic acid to the

extent of 20 per cent. of the total volume, as determined by a chemical analysis, is drawn through the gas vessel; and if, further, the scale has twenty corresponding divisions, then the movement of the pointer from one division to another will correspond to the difference in the weight of the gaseous mixture in proportion to the percentage volume of carbonic acid, and accordingly, in the practical use of the apparatus, that is to say, when smoke gases are being conducted through the gas balance, the contents of carbonic acid, as indicated by the pointer in a sufficiently accurate manner for practical purposes, may at any time be read off from the scale direct. If, for instance, the pointer points to the division line marked 12 on the scale, this would indicate that the smoke gases drawn through the vessel contain 12 per cent. in volume of carbonic acid, that is to say, the volume of the latter would amount to 12 per cent. of the whole volume of the smoke gas mixture.

If the smoke gases of a steam generator furnace when passing to the chimney have a temperature of  $270^{\circ}$  C. ( $518^{\circ}$  F.), and 12 per cent. of their total volume consists of carbonic acid, the loss of heat amounts only to about 15 per cent., but if at the same temperature the carbonic acid contents amount, for example, to only 4 per cent. of the volume of the waste gases, this would show a loss of heat of about 45 per cent., due in a great measure to the heating of an excessive quantity of air for the combustion of the fuel. Hence, it results that the gas balance herein described is of great importance as a controlling apparatus for steam generator and other furnaces, and also for obtaining the specific gravity of other gaseous mixtures by direct weighing.

A practical test of this instrument was made\* at the Baldwin Locomotive Works, in this city, with results of a very satisfactory character. The boiler furnace, from which the supply of gas was taken, was one in which anthracite coal was used. The boiler was of the Babcock & Wilcox manufacture, and its furnace setting was in no respect different from their ordinary practice. The indications of the econometer were

\* For the details of this test, consult Report No. 1973, Committee on Science and the Arts.

checked from time to time by chemical analyses of the flue gases. These analyses were by Prof. Harry F. Keller, Ph.D., of this city; each analysis was made immediately upon the withdrawal of the samples and at the place where the other tests were being conducted.

These comparative tests demonstrated the substantial accuracy of this instrument. The recorded variations show discrepancies so trifling that, if the econometer were used in the management of steam boiler furnace fires, no considerable loss would occur by reason of the difference between the econometer reading and the chemical analysis. A saving in fuel would result because of a better and more intelligent management of fire and damper, allowing less surplus air to pass through the furnace than would ordinarily be the case.

The econometer works continuously and shows automatically the percentage of carbonic acid in the gases, thus enabling the firemen to see at all times the more or less favorable conditions of combustion.

MR. JAMES CHRISTIE:—I desire to emphasize the statements made this evening—that the greatest source of loss in the furnaces of steam boilers can usually be traced to the influx of an excessive quantity of air. Combustible gases will sometimes be found in the discharge from boilers having limited combustion chambers and small fire tubes. But in ordinary conditions, with stationary boilers of the usual types, the loss from unburnt gases is generally insignificant. If we could burn all the combustible in coal, and control the admission of air nearly to theoretical requirements, say little over 12 pounds air per pound of carbon, analyses of the discharged gases would indicate over 20 per cent. of  $\text{CO}_2$ , and the free oxygen would be nearly nothing. If these gases escaped below  $500^\circ \text{F.}$ , we should evaporate over 14 pounds of water from the boiling point of water to steam at atmospheric pressure for each pound of combustible. This subject was carefully studied by the late Eckley B. Coxe, and the statement just made by the representative of the company handling his stoker, that they have found flue gases to analyze  $2\frac{1}{2}$  per cent. free O and 16 per cent.  $\text{CO}_2$ , is a very remarkable one, and a



degree of excellence I have never found. An analysis of 10 per cent. each for O and CO<sub>2</sub> is probably near the average result in ordinary combustion.

Loss through excessive dilution of air is a frequent result of improper firing, especially when the grate surface is excessive; or it occurs from leaky boiler casing, and is an argument in favor of a forced blast, instead of pulling from the rear by natural draught.

Loss from this cause is common in some of the stoker systems now in vogue, and its repression should be studied by those who desire to win favor. As an illustration, I give the condensed results of a recent extensive series of tests on boilers, both hand-fired and mechanically stoked. I am not interested in any particular boiler or stoker, therefore will not discriminate by giving names.

About twenty tests in all were made on boilers of identical make and setting, using bituminous coal, in their daily routine of work:

Method of Firing.	Water Evaporated from and at 212° per lb. of Combustible.	Efficiency of Boiler.	ANALYSES OF GASES.			Air per lb. of Combustible.	Appearance of Discharge at Chimney.
			CO <sub>2</sub>	O	CO		
Hand fired .	10.6 lbs.	70 p.c.	9.00 p.c.	11.13 p.c.	.54 p.c.	25.78 lbs.	Dense black smoke
Stoker No. 1	11.4 lbs.	76 p.c.	8.98 p.c.	8.69 p.c.	.59 p.c.	22.48 lbs.	Very light smoke
Stoker No. 2	10.2 lbs.	68 p.c.	5.8 p.c.	13.2 p.c.	.66 p.c.	40.02 lbs.	Smokeless

No boiler test is complete or determinate without analyses of the waste gases, and these frequently reveal, as in the above instances, a prolific source of previously unsuspected loss.

MR. ISAAC BOWE [Chicago]:—Your note, inviting me to participate in the discussion of the smoke question at the meeting of the Institute on September 15th, is at hand, also a copy of the past discussions of the smoke question. I shall not be able to be present in person, but send the following contribution, which you are at liberty to use as you please.

I wrote to the Board of Health of your city last spring, making inquiries whether there was any ordinance in refer-

ence to smoke, and was informed by the President of the Board that there was none, but that there had been some discussion of the advisability of such an ordinance. I did not gather from his note that the matter was in such active shape as your note indicates, otherwise I should have been only too glad to have lent my co-operation.

I was drawn into this smoke business by the fact that I was frequently consulted professionally about better and more economical methods of burning soft coal. In my investigations in that line I was early led to the point that the burning of coal without smoke must be one of the requisites of better work. For twelve years I have had an intimate experience of the joys and sorrows of the smoke business, and have faith to believe that my experience may be worth something to you in avoiding stumbling blocks.

I will take the liberty at this time to give you briefly the experience of Chicago and a little of my own. \* \* \*

The Chicago ordinance has been in force for over fifteen years, and very much has been accomplished in cleaning up the city. I think I am safe in saying that we are making fully 70 per cent. less smoke than formerly in the down-town district. Sometimes I wonder at what we have accomplished when I look back over the way it was done. The friends of decency and cleanliness have kept the ordinance alive, not, however, without a good deal of opposition. This has often been pretty stubborn and led by representative and influential men. The protests—when all the chaff was sifted out—were generally found to be not so much against the ordinance as against the way it was enforced.

The smoke inspectors enforced the ordinance just as any other ordinance was enforced; namely, from the standpoint that it was not the duty of an official to show how to comply with the law, but to compel obedience. Plainly speaking, the official attitude was this: "Your chimney smokes. Stop it, or I will haul you into court and fine you."

There is this to be said about this way of abating smoke. It is very simple, and saves lots of work, and any simpleton can fill the bill as smoke inspector, on this interpretation of his duties.

The opposition also claimed that this was the wrong way to get ready compliance and good results; that men who knew something about boilers, coal and the demands of a steam plant should be appointed as smoke inspectors. They charged that the inspectors cared not so much for the cleanliness of the city as for the devising of means for raising revenue improperly for their own pockets; that the owners of certain smoke devices, oil-burning devices and special brands of coal, said to be smokeless, were doing a suspicious amount of business, not on their merits, but as the direct work of the inspectors. However that may be (and there appears to have been some truth in the charges), the belief became general that the inspectors were crooked. Some owners of plants acknowledged they had changed furnaces, allowing themselves to be blackmailed, to get rid of the city, as they put it; others went boldly up to the captain's office to find what burner would satisfy them. They were told, as boldly, the city recommended nothing, but a way was found to convey the inspectors' wishes.

If experience is worth anything, you will readily see that it is not so important what ordinance you recommend, as to get the confidence of owners of steam plants that an honest effort is being made, and in an honest way, to get rid of the nuisance. It is much easier to keep confidence than to restore lost confidence.

I have essentially stated I did not believe a "smoke ordinance" should be enforced as ordinary laws are enforced. Instead of putting a man on the roof of a high building, with a spy-glass, to watch chimneys, I believe that men should be sent out whose duty it is to visit the boiler rooms, and that these men should be competent to suggest and advise what is best to do.

There are many reasons why this course is best, and a few of these I will mention. Correct coal burning, that is, good combustion, is a nice chemical problem, but the men who burn the coal are not generally men who have very much education, except what they have picked up in the boiler room. They know very little about the union of carbon, hydrogen and

oxygen. They do know that they have got to do certain work to get steam and keep it. To get the same results and good combustion, such men need instruction. Every furnace owner knows that the best results are obtained by his furnace when operated by a certain method and that different coals require different handling. Will inexperienced men operate a furnace, then, in a proper manner? Inexperienced men having no knowledge of firing, no knowledge of the particular burner they are called to operate, and, in fact, no knowledge of any burner, are sent into the boiler rooms here, to work, every day. Shall the owners of plants be persecuted and prosecuted until these men have learned what to do?

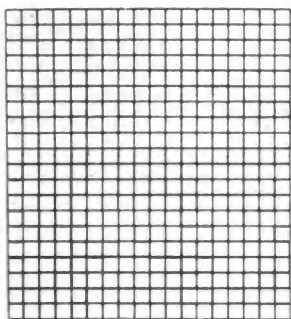
Let me further add that whatever ordinance is passed, compel the inspector to keep an open book of record; for just so sure as his work can be concealed, the owner of some cheap, inferior device, will purchase information and the inspector will be corrupted to pass it. Lastly, don't advise any **St. Louis** ordinance, as it will both hamper competition and invention. But very few men in the furnace business can afford to stand the expensive test which the **St. Louis** ordinance calls for. The tests of furnaces are utterly useless in actual practice. A furnace may give the very best results both for economy and prevention of smoke in a test, working under the most favorable conditions; but when put into the actual daily practice of a steam plant, it may, and often has, proved an utter failure. \* \* \* (Abstract of a letter addressed to the Secretary.)

#### THE RINGELMANN SMOKE SCALE.

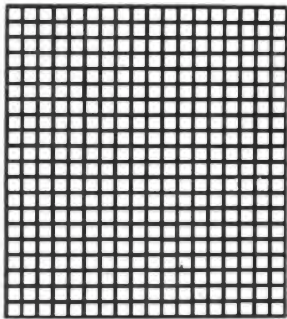
THE SECRETARY made reference to various systems in vogue for determining the relative density or blackness of smoke delivered from factory chimneys, some of which were in use with official sanction in connection with the enforcement of smoke prevention ordinances.

One of these, proposed by Prof. Ringelmann, of Paris, is said to have come somewhat extensively into use in Europe, and is favorably spoken of by Mr. Bryan Donkin, of London, who has found it useful in connection with tests of steam

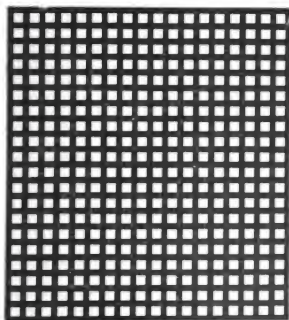
boilers and of smoke-preventing appliances. Mr. Donkin has furnished to *Engineering News* a description of the Ringelmann system, which is herewith reprinted by permission. The method appears to have the merit of great simplicity and of sufficient accuracy for practical use:



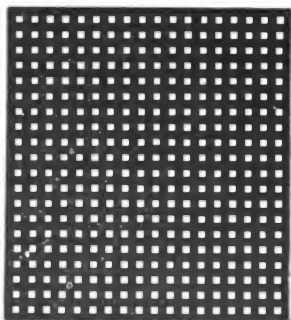
1



2



3



4

The Ringelmann smoke scale.

"In making observations of the smoke proceeding from a chimney, the four cards, on which are printed a network of black lines, together with a card which is printed in solid black, and another left entirely white, are placed in a horizontal row

and hung at a point about 50 feet from the observer, and as nearly as convenient in line with the chimney whose smoke is to be observed. At this distance the lines become invisible, and the cards with printed lines appear to be of different shades of gray, ranging from very light gray to almost black. The observer glances from the smoke coming from the chimney to the cards, which are numbered from 0 to 5, determines which card most nearly corresponds with the color of the smoke, and makes a record accordingly, noting the time when the observation was made. Observations should be made continuously during, say, one minute, and the estimated average density during that minute recorded, and so on, records being made once every minute. The average of all the records made during a boiler test is taken as the average figure for the smoke density during the test, and the whole of the record is plotted on cross-section paper in order to show in the form of a curve or broken line how the smoke varied in density from time to time.

"A rule by which the cards may be reproduced by a skilful draftsman is given by Professor Ringelmann, as follows:

Card 0, all white.

Card 1, black lines 1 mm. thick, 10 mm. apart between centres, leaving spaces 9 mm. square.

Card 2, lines 2.3 mm. thick ; spaces 7.7 mm. sq.

Card 3, lines 3.7 mm. thick ; spaces 6.3 mm. sq.

Card 4, lines 5.5 mm. thick ; spaces 4.5 mm. sq.

Card 5, all black.

"Mr. Donkin advises that the cards be made about 8 inches square each, or four times as large in area as those he furnished us, and which are here reproduced.

"It appears to us that this system of smoke grading may serve a very useful purpose. City ordinances are already in force in many places forbidding the emission of 'dense' smoke, or 'black' or 'dark gray smoke,' etc., from chimneys; but all such phrases are indefinite and can be too easily perverted to let favored parties escape and to punish those who are not favored with a 'pull' and will not purchase immunity. A city ordinance providing that the density of the smoke emitted by any chimney should not exceed that corresponding to No. 2

on the Ringelmann scale, would give a definite standard by which smoke inspectors could be governed. To burn soft coal without producing any smoke is impossible under practical conditions; but, on the other hand, proper appliances and good management can certainly prevent the emission of smoke of the density corresponding to Card 4. If a smoke ordinance requires impossibilities, it is bound to be a dead letter. If it is so interpreted as to reach only those whose chimneys emit smoke of positive blackness, it will not help much the general condition of a city's atmosphere. This scale, however, makes it possible to draw a line and state what will constitute good practice in smoke prevention."

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## GEOGRAPHY OF PRECIOUS STONES.\*

BY GEORGE F. KUNZ.

(*Concluded from vol. cxlv, p. 35.*)

Next in point of value to the ruby is doubtless ranked the beautiful green emerald. The remarkable history of emerald production has already been referred to as anciently from Mt. Zabarah, in Upper Egypt, and then the locality was completely lost sight of and abandoned for many hundreds of years, during which the source of emeralds was unknown. Then came the discovery of the New World, and the finding of these gems in the possession of the natives, obtained from the mines at Muzo, near Bogota, United States of Colombia. All of the emeralds sent to Spain at the time of the first conquest were from these mines. From that time these Bogota mines have been the principal source of this gem. For two centuries they were the only one, but about 100 years ago the emerald locality of Takowaja, in the Ural Mountains, was discovered, and for a time was a second important source. But the Ural mines have been for thirty years unworked, owing to the enormous privilege demanded by the Russian Government; and until this is changed, no

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\*A lecture delivered before the Franklin Institute, April 9, 1897. Copyrighted by George F. Kunz, 1897.

more emeralds are likely to be brought from that locality; as the fine log roads have gone to decay, and the thousands of tons of chrysotile, or asbestos, as it is erroneously and commercially called, recently discovered at a locality near the old mines, have more commercial value than the former output of the emerald mines.

It is very possible that many of the fine emeralds now in the Orient were taken there and bartered by the great jeweler and traveler, Jean Baptiste Tavernier, in the middle part of the seventeenth century.

The immense hexagonal sections of emerald that are in the jewelry that was captured from King Thebaw, of Burma, may date from this time, when the ruby mines were visited by Tavernier, and he may have exchanged the emeralds for Burma rubies.

When the emeralds of New Grenada were brought to the knowledge of Europe, it was assumed by many that here must be the long-lost source of these beautiful gems, and that in some way they must have been carried across the Pacific to the East Indies, and thence found their way to Europe. Some curious treatises were written on the supposed intercourse between America and Asia, based on this hypothetical foundation.

An equally curious discussion has been carried on for the past twenty-five years, attributing to the Mayas a Burmese origin, because jadeite is found in Burma and Mexico, and the Mexican source has not been discovered; but it may be any day, as jadeite undoubtedly has some place of occurrence in Mexico or Central America.

Garnets were evidently one of the early articles of commerce from the East, although in modern times the principal center of garnet trade and garnet cutting has been in Bohemia. Russian excavations in the Caucasus have brought to light garnets, originally very beautiful, that give evidence of a very ancient trade, probably with India. The same may, perhaps, be said of many garnet articles in other parts of Europe found in tombs of Roman, Celtic, old English, Merovingian and Carolingian date, and Etruscan and Byzantine remains.



Among these are garnet slabs or plates, garnets set in gold, as well as beads, which may have been brought by traders from Egypt or Pegu or other parts of India, rather than from Bohemia, as they are the almandine and not the pyrope variety of garnet. Six hundred establishments in Prague, Meronitz, and other parts of Bohemia give employment to 8,000 persons in the garnet industry.

Turquoise furnishes a marked illustration of the geographical changes of gem production. For ages it was only found near Nichapour in Persia, and in the Sinaitic Peninsula, and generally sold at Teheran, Cairo and at the great Russian fairs, held annually at Nijni Novgorod and at Troitsk, in Orenburg. It was carried on camels or horses to the Volga, then by steamer to Nijni Novgorod. From there it went all over the world. The Arabian mines have been largely abandoned, and all the Eastern localities had lately begun to fail, under the primitive methods there in use. But just at the time when the old sources were ceasing to yield, turquoise was discovered at several points in our own country—in New Mexico and Arizona; and the mining and production of this Oriental stone has already become an important and promising industry in the far New West. But these very mines, as now appears, were extensively though rudely worked by the pre-Columbian peoples of Central America and Mexico, and their product was highly prized and wrought into various singular objects of ornament and distinction. The stone tools and piles of *débris* of the ancient workers are conspicuous at the numerous old mines; and though these are largely abandoned and forgotten, yet traditions linger among the semi-civilized tribes of the Pueblos, of the value and sacredness of this stone to the descendants of the Aztecs and Montezuma.

Two rooms in New York office buildings, receiving packages from the mines by mail or express, sell annually more turquoise than did a host of Persian or Armenian traders, frequently traveling thousands of miles to effect sales.

As to the future of turquoise—it is a beautiful stone, and will always find a sale, although occasionally of unstable color. As an old jeweler once said: "If a lady wants a turquoise, you

can tell her a dozen times that it may change color, and that it is unstable, but she will buy it anyway." The American mines to-day yield ten times the greatest output of Persia in her palmyest days. Egypt is again furnishing fine stones. Australia may enter as a producer, and even Peru and Bolivia may yield as much as the United States, if the localities are discovered where the turquoise objects in the Montez and other Bolivian and Peruvian collections came from.

Among the curious and interesting archæological uses which turquoise has been put to are the clam shells, encrusted with turquoise to resemble toads, and the human skulls, encrusted with turquoise, now in the Brunswick collection, in the Chrystie collection in the British Museum, and the Pignori Museum in Rome; and double-headed animals resembling tigers, encrusted with turquoise, that were brought from Mexico by Humboldt, and human teeth, ornamented with turquoise, from Peru, are in the Berlin Museum.

A somewhat similar record, though without the romantic interest of prehistoric and sacred use, may be given in regard to the beautiful gem opal. This stone must have been well known to the ancients, as far back at least as Roman times, for the eminent naturalist Pliny describes it with great enthusiasm and great distinctness; but the opal for which Nonnius preferred banishment rather than parting with was evidently another gem, perhaps fractured quartz showing iridescent coloring, called "iris." The principal source has for three centuries been in Hungary, where opal-mining has been an important industry. For a long time the opal was under a cloud, owing to Scott's ill-fated Anne of Geierstein. But with the discovery of new mines, it has become popular even beyond the great supply, and thus the beauty and the profusion of this gem have dispelled the superstition of a century.

Opal is, however, largely a gem of the New World, some of the finest material coming from Mexico and Honduras, and a single Idaho opal has sold for \$1,000.

For some years past, also, magnificent opal has been brought from Queensland and from Wilcannia, New South Wales. In the latter country a journey of 600 miles from

a railroad is made to procure the gem, and beautiful precious opal replaces wood and shells, atom for atom. A recent fine opal of 271 carats was of this character. In both of these localities are found opals of matchless beauty in such abundance as to rival the greatest yield in the Hungarian mines, where the output was regulated to maintain the price.

To enter into an account of the distribution of the many different gems and precious stones that are included among the varieties of quartz would exceed the limits of this lecture. I can only refer to a few of the most important and familiar of them.

Among these we may note, first, the clear transparent quartz itself—the mineral in its purest condition—known as rock crystal, or sometimes crystal, simply. Common as this substance is in mineralogy, it is rarely found in pieces of sufficient size and clearness combined, to make it of value in the arts. It is wrought into ornamental objects—notably the crystal balls of Japan, which have long been celebrated articles of *vertu* among collectors of Oriental art. Recently these have also been cut from quartz found in Brazil, Madagascar and the United States; though but little of the American material is fine enough for this purpose.

The many centuries in which Japan was closed to the world led to an accumulation of crystal balls; but now forty years of tourist buying has drained the country, and the price has advanced fully 500 to 1,000 per cent. for perfect crystal balls over 4 inches in diameter. A perfect 6-inch ball commands \$10,000. The Ames ball, at the Boston Museum of Fine Arts, is  $7\frac{1}{8}$  inches in diameter, weighs 20 pounds, and cost over \$20,000, and yet has not the absolute perfection demanded by the collector.

Pliny describes how the quartz crystals were found in caverns in mountain sides among the Swiss Alps; how they were discovered and procured by letting men down by ropes, and then taking out the crystals. This mode of exploitation is carried on to this day in this prolific locality. During the Renaissance in Italy and Austria this was a favorite art material, and the treasures of the Louvre, the Prado in Madrid,

the Vienna, Dresden and other museums contain great quantities of priceless quartz coupes, caskets and other similar objects. The Thirty Years' War entirely broke up this art in Prague, then the great center for the work; so completely, indeed, that I was unable to obtain even a single fact regarding it in the archives of that ancient city.

In the fourteenth and fifteenth centuries, some Romans founded the industry of cutting agates and Tyrolese garnets in Fribourg, in Baden; but the frequent quarrels and raids of the knights of that time so disturbed the industry that it was withdrawn to the village of Waldkirch, a short distance from Fribourg, where 120 men and women are employed at the present time.

It was not until 1536 that agate cutting was brought still farther northward to Idar and Oberstein, in the Duchy of Oldenberg, where for 15 miles along the river Nahe the agate-cutting industry flourishes, and where now fully 30,000 people are dependent on the industry.

Doubtless many of the Cinque Cento gems, and probably some of the earlier Roman ones, were found in the amygdaloidal rocks in this vicinity, and this finding of the agates led to the founding of the industry there.

But now finer agates and similar stones are brought to these places from all parts of the world, principally from Brazil and Uruguay. Collectors go out to South America, New Zealand and the uttermost parts of the earth, and there search for these agates, with characteristic German patience, until they have succeeded in gathering a large quantity of material, which is then exported to Europe. It is then worked up at Oberstein and Idar, and wrought into an endless variety of ornamental objects, which are once more sent on their travels, and exported to all the continents—different kinds of articles being manufactured regularly for the needs and fancies of different nations and tribes, civilized and savage. Nearly all the colors are the result of staining the gray and bluish chalcedony. Thus, the agates of South America are carried to Germany, and thence find their way not only to our country and over Europe, but to the remotest parts of Africa and Asia.

When the agates are well marked and even, they afford opportunity for the cutting of cameos, and the production of many beautiful effects. In 1870 new processes were discovered, by which any piece of chalcedony could be altered into any color of onyx. Formerly onyx was always the juncture of two natural parallel layers of agate.

Next to the metallic coinage of the ancients, we have a higher art, and more history of the periods from the earliest times, recorded on the quartz gems than in all other substances combined.

In Königsberg, Prussia, a single firm controls the amber industry, and annually handles 132,000 pounds of amber, employing 1,500 people. This firm has employed for many years Professor Klebs to gather interesting amber specimens. As a result, they have a remarkable museum entirely of amber and amber articles, which is of especial ethnological interest, since they furnish amber to India, Persia, Egypt, Tripoli, Senegambia, Corea and South America, and exhibit a complete ethnological collection of amber from wherever it has been used in any time.

One of the most interesting of the semi-precious stones is that known as jade, including two species—jadeite and nephrite. These have been favorite materials for ages with many semi-savage peoples throughout the Orient, and venerated as almost sacred in China, under the name of *Yu*. An extensive ancient commerce in jade existed throughout Asia; one of the gates of the Great Wall being known as the *Yu Gate*, or jade gate. The Chinese used jade for a variety of figures and statuettes, and traded it to India, where it was wrought into other forms, as amulets, sword hilts, etc., and often inlaid with jewels and gold. Many such objects from Persia are believed to be part of the immense spoil of \$750,000,000 brought thither by Nadir Shah in 1751, after his conquest of Aurungzebe. Such are a jeweled jade mace-head, which is now in the American Museum in New York, and many fine specimens in European collections. A dark green variety, called Oceanic jade, was largely used in New Zealand and the South Pacific; and prehistoric jade celts, etc., occur through-

out Europe. A few remarkable jadeite objects have been found in the New World, but there is no reason to think that they came from Asia, as no other indications of such intercourse appear. Jadeite, indeed, occurs in worked objects, and we have not yet traced it to its finding place in America, but we will surely do so ere long, just as Lieutenant Stoney found jade in Alaska.

A recent meteor-like passing of a gem across the firmament of fashion, rising to the zenith and then falling out of sight from the height it had reached, is curiously seen in the "tiger-eye," a yellow-brown quartz cat's eye, from Griqualand. South Africa, selling from \$6 to \$10 a carat to jewelers only, but owing to the competition of two rival dealers, who sent cargoes of it to the London market, the price fell to \$1, then to 25 cents per pound by the quantity, within two years' time; and to-day it is only used in the cheapest jewelry.

Of course, in speaking of commerce in precious stones, there is no question of a great carrying trade such as we think of in food products or manufactured goods; but the questions are those that pertain to security of transportation, and greatly concentrated value. Precious stones possess three requisite qualities to make them important articles of commerce: (1) They are desirable. (2) They are scanty of supply. (3) They are readily transferable. But these same qualities also render their transportation hazardous, and require extreme precaution. In regard to the great value of precious stones, a few recent figures may not be uninteresting. A pearl necklace, weighing  $1\frac{2}{3}$  ounces, is valued at \$90,000. A diamond necklace, weighing  $1\frac{1}{2}$  ounces, at \$45,000. A small red diamond, of  $\frac{3}{8}$  carat, was sold for \$1,200, or at the rate of \$450,000 per ounce. A ruby, of  $9\frac{3}{8}$  carats, at about \$50,000, or a value of \$723,000 per ounce.

In regard to the small size or minuteness of some cut stones: Perfect brilliants are cut from 200 to 250 to the carat; in other words, from 30,000 to 37,000 to the ounce; and rose diamonds 2,000 to the carat, or 302,000 to the ounce. The highest price paid in modern times for a single stone was by the Nizam of Hyderabad, in 1892, for the Imperial or Vic-

toria diamond, of 180 carats, £400,000, or \$2,000,000, for a stone weighing 1½ ounces; in the United States \$200,000 for a pearl necklace, and a few years since over \$320,000 was paid in the United States for a diamond necklace.

In former times the gem merchant was peculiarly exposed to perils, and could only travel in the company of a caravan, or under the protection of friendly chiefs and rulers. At the present day, however, the jewels of India, Africa and Brazil are sent over the world in a different way, and with far greater safety. The caravans of the East and the diamond convoys of Brazil and the armed secret messengers of former days are replaced now by the International Postal Service. Almost all of the \$360,000,000 worth of rough diamonds taken from the South African mines have been sent to London by mail, and packages of rough stones are constantly going to and fro between the great diamond cutters of Europe, apparently without a thought of risk. The comparison with our own mail service is not complimentary to the latter.

A somewhat similar contrast may be noted between former and present conditions in regard to the keeping of precious stones and articles of jewelry. In past times the owners of such treasures had to depend either upon concealment or armed force for security in their possession.

Many of the great Oriental collections are kept in out-of-the-way rooms. Sometimes the gems are wrapped in rags, or concealed in ginger-jars, old boxes and out-of-the-way places, so that even an intimate visitor may be a guest for weeks and only occasionally see a jewel; not unless he has the entire confidence of his host are the treasures gradually brought to him one at a time, from their queer and uninviting hiding-places.

By means of safety deposit boxes, the jewels of the private owner or dealer are safer than the jewels of the imperial houses ever were, even under armed guards, or in the Duke of Brunswick's impregnable room in Paris. By the expenditure of a merely nominal sum, the family jewels now have absolute protection from theft or fire, which the monarchs of foreign lands, with their hosts of servitors, often failed to attain.

A few words as to some radical changes immediately

affecting us, are brought in by the subject of diamond cutting in the United States. Since 1868, we have imported about \$200,000,000 worth of cut diamonds, with a duty of 10 per cent. The original rough stones could not have cost more than one-half; and if the cutting had been done in this country, allowing a liberal margin for profits and interest, it would have given employment to 5,000 men for the past twenty years, at the average yearly wages of \$1,000.

It was the simple presentation of a cat's-eye engagement ring by the Duke of Connaught to his bride, in 1878, that led to a great search for the phenomenal gem, and resulted in all the phenomenal gems being sought for by Dame Fashion, stimulating the public interest in the fancy for semi-precious stones, which has increased greatly since our Centennial Exposition.

Formerly, jewelers sold only diamonds, rubies, sapphires, emeralds, opals, pearls, garnets and agates, but now it is not unusual for the mineralogical gems, such as zircon, star sapphire, star ruby, tourmaline, spinel or titanite to be called for, not only by collectors, but by the public, whose taste has advanced as much in the matter of precious stones as it has in art.

Spinel is the most valuable of the semi-precious stones, and it is one of the few minerals that are ornamental and beautiful enough for gems in their natural state. Another recent gem is the wonderfully beautiful green garnet, or demantoid, found in the gold washings in the Ural Mountains. This rivals the emerald when small, inasmuch as it has a play of fire absent in the queenly green gem. Because the name olivine strikes the ear as more pleasant, this gem has lost its identity and nearly everyone persists in calling it olivine, a name that does not belong to it.

The rapid mode of travel in modern times, when a trip around the world can be made in comfort in less time than a trip to India one way could be made in previous times, results in the gems being sent to markets instead of the traveler seeking the gems. Formerly, the dealer was a traveler, and returned with wonderful tales of the East. To-day, agates of Oberstein, opals of Australia, tiger-eye and diamonds of



the Cape, the gems of Ceylon and Burma are scattered to the uttermost ends of the world within three months, and the gems of the East go to the far West, until, as with civilization, there is no more West, or more correctly, the West is East, or rather they meet on the Pacific Coast.

Looking back on the past history of the gem traffic, as we have thus sought to outline it, we may say, that since the dawn of history the principal markets for the gathering and distribution of precious stones have been probably the following: Ancient India, Egypt, Babylon, Tyre, Alexandria, Rome, Byzantium, Venice, Augsburg, Golconda, Goa, Colombo, Ratnapura, Amsterdam, Antwerp, Paris and London. For the semi-precious stones and agates, Oberstein, in Germany, St. Claude, in the French Jura, and the great fair at Nijni Novgorod, in Russia, are the most important; and the United States is the ultimate home of from one-third to one-half of the world's product.

[The lecture was profusely illustrated throughout with the aid of lantern slides.]

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### IN MEMORIAM.

MATHEW CAREY LEA.

Our late member, M. Carey Lea, was the son of the distinguished naturalist, Isaac Lea, LL.D., and Frances A. Lea. His maternal grandfather was Mathew Carey, widely known as a publisher and writer on political economy. He was born August 16, 1823, being the second son of a family of three sons and a daughter, the eldest son dying in infancy. His brother, Henry C. Lea, the well-known publisher and writer upon historical subjects, still survives him at the age of 72. The father, who died in 1886, had reached the great age of 94.

The subject of this sketch was not sent to school or to college, but was given a very careful and thorough education by the best teachers procurable, under whose care his strong intellectual powers and retentive memory enabled him to acquire a culture at once broad and thorough in languages, literature, and the natural and physical sciences. His father's

eminence as a student of natural history, coupled with the possession of ample means, furnished exceptional opportunities for him, even as a boy, to acquire this broad culture. Thus, in 1832, when 9 years of age, he accompanied his parents to Europe, where they spent over six months in travel and making the acquaintance of the most eminent English and Continental men of science, with many of whom his father had been in correspondence for years.

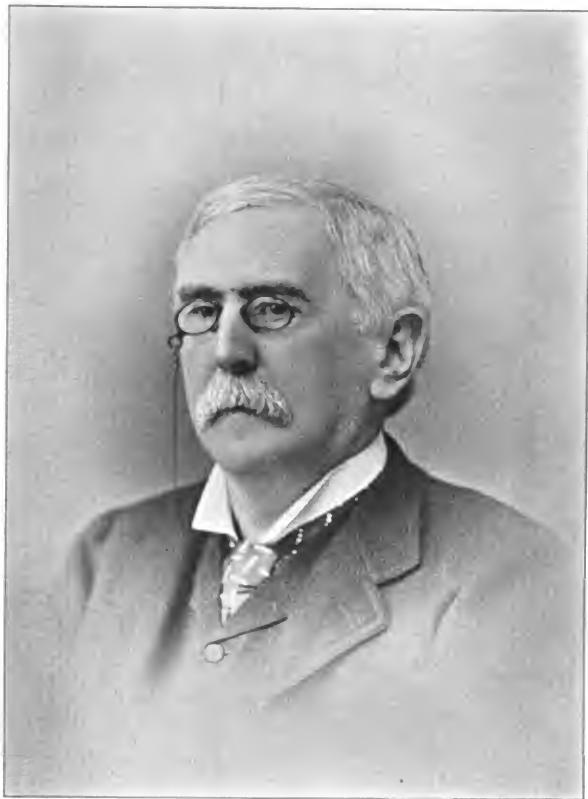
He was destined for the legal profession, and studied under the late Wm. M. Meredith, then the leader of the Philadelphia bar, and was admitted to practice about the year 1847. Ill health, not long after, forced him to abandon the profession, and he spent some years in Europe in search of relief, but from that time he remained more or less an invalid, with repeated attacks of illness, which incapacitated him for the active pursuits of life.

Shortly after abandoning the legal profession he entered the laboratory of Prof. Jas. C. Booth, and there acquired that love of chemical research to which he devoted the remainder of his life.

The branch of science which attracted him especially was the chemistry of photography. His contributions to this branch of science were numerous, and some of them of such capital importance that they secured for him a world-wide recognition as one of the half-dozen pioneer investigators who have laid the scientific foundations of photography.

From 1870 to 1878 he contributed to the photographic journals many papers of much practical value to amateur photographers on methods of preparing collodio-bromide emulsions and developing agents. Among his earlier contributions was the investigation of the influence of color on the reduction by light of the iodide, bromide and chloride of silver. Of more recent date were his experiments with a series of the salts of silver (chiefly the chlorides), with the view of making use of them in obtaining photographs of objects in their natural colors, summarized in a paper on the photo-chemistry of the silver haloids, which has been pronounced the most valuable contribution to photographic chemistry made in a quarter of a century.

(*Jour. Frank Inst.*, Vol. CXLV., February, 1898.)



M. CAREY LEA.

[1823-1897.]

He is best known to the chemical world by his description of the photo-bromide and photo-iodide of silver and the discovery of the identity of these salts with the substance of the latent photographic image, and by his remarkable discovery of the allotropic forms of silver. This extremely interesting and valuable discovery, which was published but a few years before his death, gained for him the honor of election to the National Academy of Sciences. He published, as early as 1868, his "Manual of Photography," a second edition of which appeared in 1871.

Along with these scientific studies he kept up his interest in literary culture, and his intimate acquaintance with the classics, and with what is best in the literature of Europe, of England, France, Germany, Italy and Spain, with all of the languages of which he was familiar.

Mr. Lea united himself with the Franklin Institute in 1848, and with the Chemical Section shortly after its organization. Although never participating actively in the work of the Institute, he manifested his appreciation of its rich possessions of scientific serials by availing himself frequently of the special privileges which the Library Committee was pleased to accord him, in recognition of his devotion to scientific research. The value which he placed upon the advantages thus derived from his connection with the Institute was manifested in his bequest to the Chemical Section of his large and valuable collection of physical and chemical apparatus and material and scientific books, and a fund to provide (in perpetuity) for the purchase of books and periodicals devoted to physics and chemistry.

He was twice married, first to Elizabeth Jaudon, widow of William Woodhouse Bakewell, of Cincinnati, who died in 1881, leaving a son, George H. Lea, and, secondly, to Eva Lovering, daughter of the late Prof. Joseph Lovering, of Harvard University. His son and widow survive him.

His death occurred at his residence at Chestnut Hill, Philadelphia, on the 15th of March, 1897.

S. P. SADTLER,  
JNO. CARBUTT,  
WM. H. WAHL.

## APPENDIX.

## LIST OF THE MORE IMPORTANT SCIENTIFIC PAPERS OF M. CAREY LEA.

Numerical Relations between Chemical Equivalents. *American Journal of Science*, vols. I and II, 1860.

Production of Ethylamine by Reactions of the Oxy-ethers. *American Journal of Science*, vol. II, 1860.

Sources of Error in the Detection of Potash. *American Journal of Science*, vol. I, 1861.

Production of Ethyl-bases. *American Journal of Science*, vol. II, 1861.

Exact Separation of Ethyl-Bases. *American Journal of Science*, vol. II, 1861.

Preparation of Ethyl Nitrate and Nitrite. *American Journal of Science*, vol. II, 1861.

Reactions of Ethylamine and Diethylamine. *American Journal of Science*, vol. I, 1862.

Production of Methyl-bases and Formation of Methyl Nitrate. *American Journal of Science*, vol. I, 1862.

On Methylamine. *American Journal of Science*, vol. I, 1862.

On Triethylamine. *American Journal of Science*, vol. II, 1862.

Arithmetical Relations of Chemical Equivalents. Influence of Ozone and other Chemical Agencies on Germination and Vegetation. *American Journal of Science*, vol. I, 1864.

Remarks on the Distillation of Substances of Different Volatilities. *American Journal of Science*, vol. I, 1864.

Notes on the Platinum Metals and their Separation from each Other. *American Journal of Science*, vol. II, 1864.

Notes on the Reactions of the Platinum Metals. *American Journal of Science*, vol. II, 1864.

Colored Derivatives of Naphthaline. *American Journal of Science*, vol. II, 1864.

Preparation of Oxalate of Ethyl. *American Journal of Science*, vol. I, 1865.

Reactions of Gelatine. *American Journal of Science*, vol. II, 1865.

Nature of the Invisible Photographic Image. *American Journal of Science*, vol. II, 1865.

Detection of Iodine. *American Journal of Science*, vol. II, 1866.

Nature of the Action of Light on Silver Iodide. *American Journal of Science*, vol. II, 1866.

New Manipulations. *American Journal of Science*, vol. II, 1866.

Influence of Organic and Inorganic Substances on Germination and Vegetation. *American Journal of Science*, vol. I, 1867.

Contributions toward a Theory of Photo-Chemistry. *American Journal of Science*, vol. II, 1867.

New Test for Hyposulphites. *American Journal of Science*, vol. II, 1867.

On Nitroglucose. *American Journal of Science*, vol. I, 1868.

Criticism on a Proposed Method of Estimating Ethylic Alcohol in Presence of Methyl. *American Journal of Science*, vol. I, 1872.

Influence of Color on Reduction by Light. *American Journal of Science*, vol. I, 1874.

Laboratory Notes. *American Journal of Science*, vol. I, 1874.

Nature of Action of Light on Silver Bromide. *American Journal of Science*, vol. I, 1874.

Detection of Hydrocyanic Acid. *American Journal of Science*, vol. I, 1875.

Action of the less Refrangible Rays on Silver Iodide and Bromide. *American Journal of Science*, vol. I, 1875.

Influence of Color on Reduction by Light. *American Journal of Science*, vol. I, 1875.

Explosive Properties of Methyl Nitrate. *American Journal of Science*, vol. II, 1875.

Notes on Sensitiveness of Silver Bromide to Green Rays as Modified by other Substances. *American Journal of Science*, vol. I, 1876.

Sensitiveness to Light of Various Salts of Silver. *American Journal of Science*, vol. I, 1877.

On Certain New and Powerful Means of Rendering Visible the Latent Photographic Image. *American Journal of Science*, vol. II, 1877.

Action of Certain Organic Substances in Increasing the Sensitiveness of the Silver Haloids. *American Journal of Science*, vol. II, 1877.

Reactions of Silver Chloride and Bromide. *American Journal of Science*, vol. I, 1878.

On Ammonio-argentic Iodide. *American Journal of Science*, vol. I, 1878.

On Combinations of Silver Chloride and Iodide with Coloring Matters. *American Journal of Science*, vol. I, 1885.

On Red and Purple Chloride, Bromide and Iodide of Silver. On Heliochromy and on the Latent Photographic Image. *American Journal of Science*, vol. I, 1887.

Identity of the Photosalts of Silver with the Material of the Latent Photographic Image. *American Journal of Science*, vol. I, 1887.

On Photo-bromide and Photo-iodide of Silver. *American Journal of Science*, vol. I, 1887.

Image Transference. *American Journal of Science*, vol. II, 1887.

Combinations of Silver Chloride with other Metallic Chlorides. *American Journal of Science*, vol. II, 1887.

On Allotropic Forms of Silver. *American Journal of Science*, vol. I, 1889.

On Allotropic Forms of Silver. *American Journal of Science*, vol. II, 1889.

On the Properties of Allotropic Silver. *American Journal of Science*, vol. II, 1889.

On Ring Systems and other Curve Systems produced on Allotropic Silver by Iodine. *American Journal of Science*, vol. II, 1889.

On Gold-colored Allotropic Silver. *American Journal of Science*, vol. I, 1890.

On Allotropic Silver. *American Journal of Science*, vol. I, 1891.

On Allotropic Silver. (Read before the National Academy of Sciences, April 24, 1891, by Prof. Ira Remsen).

On Allotropic Silver, Blue Silver, Soluble and Insoluble Forms. *American Journal of Science*, vol. I, 1891.

Notes on Allotropic Silver. *American Journal of Science*, vol. II, 1891.

# Franklin Institute.

[*Proceedings of the annual meeting held Wednesday, January 19, 1898.*]

HALL OF THE FRANKLIN INSTITUTE,  
PHILADELPHIA, January 19, 1898.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 163 members and visitors.

The annual report of the Board of Managers, the reports of the various Committees and Sections, and of the Trustees of the Elliott Cresson Medal Fund, were presented. They were accepted and ordered filed. (*See Appendix.*)

The Secretary presented letters of thanks to the Institute from the New England Cotton Manufacturers' Association and the Local Committee of Entertainment, for courtesies extended to members of the Association on the occasion of the meeting that body in Philadelphia, on October 27-28, 1897.

Dr. A. C. Crehore, of Hanover, N. H., and Lieut. Geo. O. Squier, U.S.A., presented a joint communication on the Synchronograph, a system invented by them for the rapid transmission of intelligence by the use of the alternating current. The communication embraced a description of the general principles of the system, and an account of the tests lately made, under the direction of Mr. W. H. Preece, Engineer-in-chief of the British Postal System, in operating the Wheatstone instruments by the alternating current, according to the synchronograph method devised by the authors.

Mr. Melvin L. Severy, of Boston, Mass., described and showed in practical operation, the Severy impression process. This is claimed to be an improvement upon the present method of printing, by the use of which an instantaneous and perfect adjustment of the printing surfaces is secured *automatically*, thus dispensing with the tedious and expensive operation known as "make-ready." (Referred to the Committee on Science and the Arts for investigation and report.)

Mr. H. H. Gross described and illustrated the construction and principle of operation of the so-called "Luxfer" prisms. This invention is designed to secure the more efficient diffusion of light in basements, vaults, and poorly-lighted apartments generally. (Referred to the Committee on Science and the Arts for investigation and report.)

The report of the tellers of the annual election was presented. The result of the election was as follows:

For <i>President</i>	(to serve one year), . . . . .	JOHN BIRKINBINE.
" <i>Vice-President</i>	( " three years), . . . . .	GEORGE V. CRESSON.
" <i>Secretary</i>	( " one year), . . . . .	WM. H. WAHL.
" <i>Treasurer</i>	( " " ), . . . . .	SAMUEL SARTAIN.
" <i>Auditor</i>	( " three years), . . . . .	JOHN GEORGE COPE.
" "	(for the unexpired term of J. H. Cooper, deceased), . . . . .	WM. H. GREENE.

For *Managers* (to serve three years).

GEORGE H. FRAZIER,  
ALFRED C. HARRISON,  
HENRY R. HEYL,  
HERBERT M. HOWE,

ALEX. KRUMBHAAR,  
C. HARTMAN KUHN,  
SAMUEL M. VAUCLAIN,  
GEORGE VAUX, JR.

For the *Committee on Science and the Arts* (to serve three years).

L. L. CHENEY,  
JAMES CHRISTIE,  
LUIGI D'AURIA,  
J. M. EMANUEL,  
WM. PENN EVANS,

J. LOGAN FITTS,  
CHAS. A. HEXAMER,  
JACOB Y. McCONNELL,  
CLAYTON W. PIKE,  
STACY REEVES,

LINO F. RONDINELLA,  
A. J. ROWLAND,  
SAMUEL SARTAIN,  
T. CARPENTER SMITH,  
THOMAS SPENCER.

The tellers received a vote of thanks for their services.

Adjourned.

WM. H. WAHL, *Secretary*.

## COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held January 5, 1898.*]

MR. JAMES CHRISTIE in the chair.

Reports on the following subjects were considered :

*Compound Locomotive Engine*.—Clifton L. Reeves, Trenton, N. J. (First reading.)

*Process and Apparatus for Manufacturing Carbureted Water-gas*.—Henry C. Rew, Chicago, Ill. Discussed and referred back to sub-committee with additional members.

*Wave Motors*.—Henry Lotzgesell, Philadelphia. Referred back to sub-committee.

*Steel-Lined Aluminum Culinary Ware*.—Romain C. Cole, New York. Referred back to sub-committee.

*Franklin Institute Grand Medal*. Held under advisement.

*Balanced Driving Wheel for Locomotives*.—Philip Z. Davis, Philadelphia. Reconsidered on the applicant's request, to permit him to present new evidence of the utility of his invention.

[An abstract of this Committee's annual report is incorporated in the Annual Report of the Board of Managers, printed elsewhere in this impression of the *Journal*.]

W.



## SECTIONS.

CHEMICAL SECTION.—*Stated Meeting* held Tuesday, 18, 1898. President, Dr. Lee K. Frankel, in the chair.

Prof. W. C. Day presented a communication "On the Action of Carbon Dioxide on Sodium Aluminate and on the Formation of a Basic Aluminium Carbonate." Discussed by Dr. Keller, Prof. Bradbury and the author.

Prof. F. A. Genth, Jr., gave an oral account of an observation he had made in reference to the detection of salicylic acid in food products, which seemed to indicate that the accepted method was unreliable. The communication was announced to be a preliminary one, and further information on the subject was promised in the near future.

The following officers were elected for the year 1898, viz. :

President—Dr. Lee K. Frankel.

Vice-Presidents—Dr. Bruno Terne and Dr. W. J. Williams.

Secretary—Mr. Lyman F. Kebler.

Conservator—Dr. Wm. H. Wahl.

The accompanying Annual Report of the Section was approved, and ordered to be transmitted to the Institute :

JANUARY 1, 1898.

## TO THE COMMITTEE ON SECTIONAL ARRANGEMENTS.

*Gentlemen :*

I am directed to submit the following report of the operations of the Chemical Section, during the year 1897.

The officers of the Section were :

President—Dr. Joseph W. Richards.

Vice-Presidents—Dr. Bruno Terne and Dr. Lee K. Frankel.

Secretary—Mr. Lyman F. Kebler.

Conservator—Dr. Wm. H. Wahl.

The Section has held stated monthly meetings as required by the by-laws of the Institute, on the third Tuesday of each month (except in July and August).

A list of communications presented and discussed is hereto appended. In addition to these, four evenings were devoted to lectures on subjects germane to the objects of the Section. These are also listed. A number of these contributions have appeared in the *Journal*.

The membership of the Section at the close of 1896 was 106. During the year 1897 there were added to the roll six new members. The losses of membership during the year were seven, leaving a net membership at the close of 1897, of 105, a decrease of 1.

A circumstance of much importance, as affecting the prosperity of the Section, was reported during the year 1897, viz., the bequest to the Section, by its deceased member, Mr. M. Carey Lea, of his scientific library and apparatus, and of the income of a piece of real estate, to provide a permanent fund for the purchase of books and periodicals devoted to chemistry and physics.

The books and physical and chemical apparatus received from this bequest represent a value of several thousand dollars, and, as soon as the needful facili-

ties can be furnished, the latter will be made available to the members, under proper restrictions. The income of the book fund, it is expected, will become available during 1898, and will probably amount to about \$150 yearly.

Following is a list of the lectures and communications presented to the Section during the past year :

## LECTURES.

Feb. 16th, Wiley (Dr. H. W.). "Soil Microbes Useful in Agriculture."

April 20th, Leffmann (Dr. Henry). "The Chemistry of Food Adulteration."

June 15th, Richards (Dr. Jos. W.). "A Critical Review of Methods of Determining Minerals."

Nov. 16th, Terne (Dr. Bruno). "Ammonia and its Sources."

## COMMUNICATIONS.

Jan. 19th, Nitze (H. C. B.). "Recent Developments in the Magnetic Treatment of Ores, Describing the Wetherill Magnetic Concentrator."

Jan. 19th, Richards (Dr. Jos. W.) and Thomson (J. A.). "Recent Determinations of the Electric Conductivity of Aluminium."

Jan. 19th, Kebler (Lyman F.). "Volumetric Estimation of Acetone."

Jan. 19th, Richards (Dr. Jos. W.). "A New Laboratory Grinder."

March 16th, Leonard (C. L.). "The Permeability of Different Qualities of Aluminium to the Roentgen Rays."

March 16th, Richards (Dr. Jos. W.). "The Relation Between the Latent Heat of Fusion of the Elements and their Melting Points."

May 18th, Shapleigh (Waldron). "Notes on Lucium."

May 18th, DuBois (H. W.) and Mixer (C. T.). "On the Determination of Insoluble Phosphorus in Iron Ores."

May 18th, Keller (Dr. H. F.) and Maas (Philip). "Some New Derivatives of Diacetyl."

Sept. 21st, Sadtler (Prof. S. P.). "Formation of Petroleum from Linseed Oil."

Sept. 21st, Sadtler (Prof. S. P.). "Remarks on Peanut Oil."

Oct. 19th, Keller (Dr. H. F.). "Analysis of Electrolytic Copper."

Oct. 19th, Maas (Philip) and Keller (Dr. H. F.). "Vanadium Minerals from Leadville, Col."

Dec. 21st, Peckham (S. F.). "Chemistry of the California Petroleums."

Respectfully submitted by order of the Section.

LYMAN F. KEBLER, *Secretary*.

ELECTRICAL SECTION.—*Stated Meeting* held Tuesday, January 11, 1898. President, W. E. Harrington in the chair.

Mr. David Pepper, Jr., read a paper on "Line and Return-Circuit Construction of Electric Railways." (Referred for publication.)

## ANNUAL REPORT :

PHILADELPHIA, January 16, 1898.

TO THE COMMITTEE ON SECTIONAL ARRANGEMENTS.

Gentlemen :

I beg to submit a report of the work of the Electrical Section during the year 1897.

The following papers were presented :

- Jan. C. J. Reed—New Induction Telegraph Apparatus.  
 Wm. C. L. Eglin—"Some Tests on Enclosed Arc Lamps."  
 Feb. Wm. H. Weston—"Sub-division of Rheostat Coils."  
 Mar. C. J. Toering—"Enclosed Arc Lamps."  
 April. H. L. Sayen—"New Form of Crookes Tube with Automatically Adjustable Vacuum."  
 May. Jos. Sachs—"Electric Elevators."  
 E. G. Willyoung—"Circuit Breakers for Induction Coils."  
 Oct. C. E. Carpenter—"Electric Current Controlling Devices."  
 Prof. W. D. Marks—"Electric Meters."  
 Nov. J. L. Woodbridge—"The Booster System applied to Electric Railways."  
 W. E. Harrington—"Railway Bonding."  
 Dec. Mark A. Replogle—"Speed Government in Water Powers."  
 Paul A. Winand—"The Constant Current Transmission of Power."

The increase in membership during the year has been gratifying, while the loss of old members by resignation or otherwise has been trifling.

A considerable increase in the average attendance, which has been during the year about sixty, is an even better guarantee of the interest in the work of the Section.

Respectfully yours,

CLAYTON W. PIKE, *President*.

MINING AND METALLURGICAL SECTION.—*Stated Meeting* held Wednesday, January 12, 1898. President, Benj. S. Lyman, in the chair.

Mr. Pedro G. Salom read a paper on "The Electrolytic Production of Lead from Galena." The method is based on the reduction of lead directly from the sulphide ore, in an electrolyte of aqueous sulphuric acid through the agency of hydrogen. The paper was discussed by Mr. C. J. Reed and the author. The author submitted specimens of lead sponge and various oxides of lead obtained in his process. (Referred for publication.)

Mr. Benj. S. Lyman presented a communication entitled: "Some Illustrations of the Influence of Geological Structure on Topography." (Referred for publication.)

The following officers were elected for the year 1898, viz. :

President—Mr. A. E. Outerbridge, Jr.

Vice-Presidents—Dr. David K. Tuttle and Mr. James Christie.

Secretary—Mr. Wm. C. Henderson.

Conservator—Dr. Wm. H. Wahl.

The accompanying annual report of the Section was approved and ordered to be transmitted to the Institute. viz. :

#### TO THE COMMITTEE ON SECTIONAL ARRANGEMENTS.

*Gentlemen :*

In presenting this first annual report of the Mining and Metallurgical Section of the Franklin Institute, it has been thought of possible interest to enter upon a resumé of the events that have led to establishing this Section.

The Mining and Metallurgical Section is the outgrowth of the Committee on Minerals and Geological Specimens; it owes its existence to the untiring efforts of Mr. Benj. Smith Lyman, chairman of that committee, who, in a letter to Mr. John Birkinbine, President of the Institute, dated February 20, 1897, brought the matter up in the following terms:

"Before any final decision of the fate of our Committee on Minerals and Geological Specimens, it may be worth while to consider an idea or two that have occurred to me \* \* \* It has long seemed quite possible that so large a number of men, members of the American Institute of Mining Engineers, interested in mining and metallurgy, and inclined to associate themselves with others, might find it agreeable, useful and convenient to meet for paper reading and discussion, and social intercourse, more frequently than the half yearly, generally distant meetings of the Institute \* \* \* A close association and frequent meeting of mining engineers and metallurgists, under the Franklin Institute, would cost them no additional annual fee (unless they chose to increase the attraction by a small subscription for some slight refreshment); they would have the pleasure, instruction and manifold profit of a society; and perhaps could publish some of their valuable results in the FRANKLIN INSTITUTE JOURNAL \* \* \* The proposed Association of Mining Engineers and Metallurgists in the Franklin Institute might either be organized as a Mining Section, or a Mining and Metallurgical Section."

At the meeting of the Committee on Minerals and Geological Specimens, held March 10, 1897, Mr. Lyman laid the matter of the organization of a Mining and Metallurgical Section before the committee, and it was finally decided to issue to such persons as it was thought would be interested, the circular letter which bears the date of March 31, 1897, the purpose of the letter may be gathered from the following extract:

DEAR SIR:—The Standing Committee on Minerals and Geological Specimens of the Franklin Institute has done nothing for many years past, as the specimens have been deposited with the Academy of Natural Sciences, but now desires to become active again, with perhaps some modification of scope or of organization, and requests your co-operation in forming an important Mining and Metallurgical Museum, and a Mining and Metallurgical Section of the Institute. \* \* \* You are invited to signify your approval of the plan by signing the enclosed card and returning it to the Franklin Institute, so that, if there be reasonable encouragement, a meeting may be shortly called to organize the Section.

By order of the Committee on Minerals and Geological Specimens.

BENJ. SMITH LYMAN,

*Chairman.*

This letter evoked a favorable response from sixty-two persons. Upon this encouragement a meeting was called for the evening of April 28, 1897. This inaugural meeting was attended by thirty-five persons, the Section was organized, and at the adjourned meeting, held May 12, 1897, the following officers were elected to serve during the year:

President—Mr. Benj. Smith Lyman.

Vice-Presidents—Dr. D. K. Tuttle, Mr. A. E. Outerbridge, Jr.

Secretary—Mr. Wm. C. Henderson.

Conservator—Dr. Wm. H. Wahl.

Six meetings have been held during the year, with an average attendance of thirty. There have been read before the Section eleven papers, as follows :

(1) "Mechanical and Engineering Progress as Influenced by the Mining Industry," John Birkinbine.

(2) "The Undeveloped Mineral Wealth of Newfoundland," A. E. Outerbridge, Jr.

(3) "Compass Variation as Affected by Geological Structure in Bucks and Montgomery Counties, Pa.," B. S. Lyman.

(4) "Underground Water Supply," F. L. Garrison.

(5) "Monazite," H. B. C. Nitze.

(6) "A Special Process for Treating Cast Iron," Charles James.

(7) "Some Remarks on Wire-Glass," Francis Schumann.

(8) "Copper Traces in Bucks and Montgomery Counties, Pa.," B. S. Lyman.

(9) "Forestry as Related to Geology and Engineering," John Gifford.

(10) "Kryolith: its Mining, Preparation and Utilization," Wm. C. Henderson.

(11) "Fatigue of Metals in Iron and Steel Forgings," H. F. J. Porter.

The membership to date consists of seventy-three persons.

Quite a number of interesting communications have been promised for the near future, among which may be mentioned :

(1) "The Electrolytic Production of Lead from Galena," Pedro D. Salom.

(2) "The Practical Aspect of Present Methods of Testing Iron and Steel," Paul Kreuzpointner.

(3) Building Stones," Alexis A. Julien, Ph.D.

(4) "The Development of the American Portland Cement Industry," Robert W. Lesley.

(5) "The Secret of the Strait," Lewis M. Haupt, C.E.

(6) "Gold Mining in Georgia," William Tatham.

(7) "Japanese Swords," Capt. E. L. Zalinski.

(8) "The Supply of Iron Ore," John Birkinbine.

At present the outlook for the Section's future seems very encouraging, and it is believed by those most interested in its welfare that the Mining and Metallurgical Section has fairly entered upon a field of great usefulness and prosperity.

By direction of the Mining and Metallurgical Section.

WM. C. HENDERSON,  
*Secretary.*

# ANNUAL REPORT OF THE BOARD OF MANAGERS OF THE FRANKLIN INSTITUTE.

(For the year 1897.)

The Board of Managers of the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts respectfully presents the following report of the operations of the Institute for the year 1897 :

## MEMBERS.

Members at the close of 1896 . . . . .	1,867	
Number of new members elected who have paid their dues in 1897 . . . . .	100	
		1,967
Lost by death, resignation and non-payment of dues,		129
Total membership at the end of 1897 . . . . .		1,838

## LIBRARY.

The additions to the Library during the past year numbered nearly 3,000 new titles, a gratifying exhibit in view of the diminished income of the Committee. This good showing was made possible through the accession, by bequest, of the valuable private library of the late M. Carey Lea. The storing of the library in the new fire-proof stack-room, now almost ready for their reception, will insure the safety of these invaluable literary treasures, and will be a cause for satisfaction to the members of the Institute. It may not be amiss to note the fact that, exclusive of a considerable number (about 5,000) of maps, charts, etc., the library of the Institute at present contains the imposing number of 80,000 books and pamphlets. As a large proportion of this collection is composed of serial publications used for study and reference, and as many of the books are long out of print and difficult of replacement if lost or destroyed, the course adopted by the managers, in making provision for the better security of the library, it is believed, will be cordially approved by the members.

## JOURNAL.

The financial statement of the *Journal* for the year 1897 (see appendix) exhibits a slight improvement in the receipts, over those for the previous year, although this increase is not as large as was anticipated when the year began. The Committee on Publications reports that the prospect for the present year is encouraging, and affords reasonable basis for the hope that the next accounting will exhibit a surplus.

The service rendered to the library by the exchanges of the *Journal*, though it does not appear in its cash account, is invaluable, and represents annually the addition of about \$1500 worth of the most valuable class of current scientific and technical literature.

The Board desires to express its high appreciation of the services rendered to the Institute by the editorial branch, and of the care and economy with which the business affairs of the *Journal* have been conducted by the Committee on Publications.

## COMMITTEE ON SCIENCE AND THE ARTS.

This Committee has exhibited its customary activity during the past year. The cases received for investigation, or referred to the Committee by the Institute, numbered 46. The number of cases reported upon, or otherwise disposed of, was 52. There have been awarded or recommended, through this Committee's agency, of Elliott-Cresson Medals, 4; of John Scott Premiums and Medals, 11; of Edward Longstreth Medals, 5, and of Certificates of Merit, 1. In 20 cases no awards were made.

## OTHER COMMITTEES.

During the past year, the attempt was made to revivify several of the standing committees, whose work for many years had been allowed to fall into abeyance.

*The Committee on the Cabinet of Arts and Manufactures* has held several meetings during the year. It reports that while a Cabinet of Arts and Manufactures does not at present exist, and while there are grave doubts as to the advisability of undertaking to establish one, it is possible that in the clearing and rearranging of the building, incident to the removal of the books to the new stack, or at an exhibition that may be held in the near future, there may be found material which it will be the province of this committee to arrange and care for.

*The Committee on the Cabinet of Minerals and Geological Specimens* likewise has held several meetings at which, the question of its present and future operations was considered. It was ascertained that the small collection at one time in possession of the Institute had been deposited—some fifteen years ago—with the Academy of Natural Sciences, for the reason that the room in which it had been displayed was needed for the Drawing School.

The Committee considered that the general purposes for which it had originally been instituted could be much better subserved by a Section of Mining and Metallurgy to be devoted to the promotion of these and kindred branches of applied science, for the formation and maintenance of which the present by-laws of the Institute make liberal provisions.

The outcome of the Committee's discussion of these matters was the formation of a Section on the lines above indicated, which was authorized by the Board at its stated meeting of April 14, 1897. This Section has at present a membership of 73, and has fully justified the hopes of its founders as to its utility.

The Committee concludes its annual report with the statement that this Section meets the present needs and opportunities in its special field so fully that there no longer exists any substantial reason for the Committee's continuance, and recommends accordingly that it be discontinued.

*The Committee on Meteorology* met several times during the year for the reading and discussion of professional papers, and also for the consideration of the question of its future work. With reference to this, the following statements are contained in the Committee's annual report.

“Respecting the future of the Committee, there is room for differences of opinion, but since the diversion of the work of the State Weather Service from the control of the Institute, several years ago, there appears to be nothing in sight with which the Committee could actively employ its members,

with direct advantage to the Institute, that could not be much better and much more effectively undertaken through the instrumentality of a Section devoted to Meteorology and Climatology.

"The liberal provisions of the By-laws of the Institute afford an easy method by which all members who are interested in this branch of science may become associated, for the purpose of pursuing it with greater possible benefit to themselves and to the Institute, than through the instrumentality of a committee restricted in membership to ten persons.

"The Committee on Meteorology, therefore, would respectfully suggest that it be discontinued, and that an effort be made to create in its stead a Section of Meteorology and Climatology."

*The Committee on Meetings* has held regular sessions during the year, the results of which have appeared in the programs of the stated meetings of the Institute, printed in the *Bulletin* issued monthly under the Committee's direction, and sent to all members in good standing.

At the ten stated meetings of the Institute, seventeen papers and other communications were presented, some of which were of considerable importance. This is especially true of the "Smoke Prevention" question, referred to the Institute by the Bureau of Health, of Philadelphia, which called forth an extended discussion, and which included the presentation of descriptions of all the important forms of improved furnaces and automatic stokers in use throughout the country. The conclusions reached by the Institute, as the result of the careful consideration which the subject received, will shortly be officially laid before the Bureau of Health, and, it is believed, will prove of substantial service in the framing of legislation on the subject, which is now admitted to be necessary.

*The Committee on the Cabinet of Models* has held several meetings, at which it was decided to make a complete examination of all the models in possession of the Institute with the view of making a judicious selection of the same, reserving for classification, cataloguing and preservation those which appear to have sufficient value, and discarding such as seem to be valueless. The Committee had made considerable progress with this work, when its members were compelled to suspend the work on account of the building alterations decided on by the Board. The Committee intends to resume and complete its work as soon as opportunity is afforded.

#### LECTURES.

*The Committee on Instruction*, with the co-operation of the professors, succeeded during the past year in arranging a more miscellaneous and generally useful series of lectures than heretofore.

In view of the difficulty heretofore experienced in attracting large audiences to the lecture-room of the Institute to listen to lectures of a technical character, it was decided to assign all such to one or another of the Sections, in the form of communications for reading and discussion. This course has proved satisfactory, not only by increasing the activity and importance of the Sections, but also by affording the contributors of technical papers a select and more appreciative audience of experts.

In furtherance of this general scheme, arrangements were made with the officers of Central Branch of the Young Men's Christian Association, for



giving six of the most attractively illustrated lectures, in the more commodious and centrally-located hall of the Association, at Fifteenth and Chestnut Streets, without charge for rental, and with the sole condition that they were to be announced as given under the joint patronage of the two societies.

Thus far the experiment has proved highly satisfactory. The attendance has been large, and the members of the Institute have very generally availed themselves of the opportunity of profiting by the arrangement.

The Board calls attention to the fact that, as in previous years, its Committee on Instruction has been able to obtain the services of its lecturers (many of whom are men of distinguished reputation) without remuneration, the sincerest evidence that could be presented of the respect in which the Institute is held. The Board recommends that the Institute should testify its appreciation of the gratuitous services of its lecturers by the passage of a vote of thanks.

#### DRAWING SCHOOL.

The attendance of pupils in the Drawing School, and in its Branch School at Germantown Junction, shows a slight increase over the previous year, encouraging the hope that the steady diminution in the number of pupils that we have had to note for the past three or four years, has at length been arrested.

The efficiency of the Schools has been fully maintained.

The expediency of establishing, in connection therewith, classes for instruction in mathematics is under consideration.

#### SECTIONS.

The Chemical and Electrical Sections exhibited during the past year a commendable degree of activity, and the character of the professional papers read and discussed at the meetings (many of which have enriched the pages of the *Journal*) amply demonstrated the utility of affording the members the fullest opportunity to form such associations within the Institute for mutual improvement and as a stimulus for the advancement of the Arts and Sciences.

The Institute has been strengthened during the past year by the formation of a new Section devoted to Mining, Metallurgy and kindred branches of applied science. This Section has already a large membership, and, from the interest taken in its meetings, gives promise of an active and useful career.

The programs of the Electrical and Mining and Metallurgical Sections, as will appear from an inspection of the list of papers printed in the announcement book, have been so well filled as to have made it necessary, in a number of instances, to increase the number of meetings to two in each month.

#### GENERAL REMARKS.

Summarizing the results of the work of the past year, it may fairly be stated that every branch of the Institute has made the best possible use of its opportunities for active work. The serious limitations which lack of funds and lack of space have imposed upon the Committees and the Sections are too well known to need repetition.

The present improving condition of general business encourages the hope that the Endowment Committee, lately established by your Board, may be successful in its efforts to secure a substantial sum by subscription to provide a maintenance fund, out of the income of which the current work of the Institute may be conducted on a scale of proper efficiency.

The alterations in the building, now approaching completion, were determined upon by your Board after the most careful consideration. When completed, it is believed that the greater safety to the library which will be secured thereby, and the large amount of room for reading tables, the display of interesting models and other uses, that will be gained by the change will be found most satisfactory, and that the advantages the members will derive therefrom will amply justify the Board's action.

The Institute's financial statement for the year 1897 is hereto appended.

By order of the Board,

JOHN BIRKINBINE, *President.*

HALL OF THE INSTITUTE, PHILADELPHIA, January 12, 1898.

# APPENDIX.

## FINANCIAL STATEMENT FOR THE YEAR 1897.

Balance on hand, January 1, 1897 . . . . .		\$196 99
<i>Receipts:</i>		
*Committee on Publications . . . . .	\$2,802 78	
Committee on Library . . . . .	26 30	
Committee on Instruction . . . . .	807 00	
Committee on Science and the Arts . . . . .	151 20	
Committee on Meetings . . . . .	16 50	
Curators . . . . .	11 50	
Committee on Stocks and Finance . . . . .	633 33	
Income Bloomfield H. Moore Memorial Fund . . . . .	785 90	
Income Memorial Library Fund . . . . .	55 45	
Frederick Graff Fund . . . . .	3 00	
Interest on Investments of funds in the hands of the Board of Managers . . . . .	940 00	
Income from Endowments in the hands of the Board of Trustees . . . . .	2,023 25	
Receipts from Members, annual . . . . .	5,780 25	
Receipts from Life Memberships . . . . .	392 00	
Entrance Fees Non-Resident Members . . . . .	145 00	
Interest on bank deposits . . . . .	14 87	
Receipts from sales of Index to <i>Journal</i> . . . . .	35 00	
Receipts from sales of Exhibition Reports . . . . .	12 65	
Receipts from sales of Membership Certificates . . . . .	5 00	
Electrical Section (a donation to) . . . . .	31 00	
Temporary Loan . . . . .	2,000 00	
Scott Legacy Premiums . . . . .	200 00	
Proceeds of Sales of Central Railroad of New Jersey Bonds . . . . .	2,200 70	
Interest on B. H. Bartol Fund . . . . .	50 00	
		<hr/> \$19,122 68
<i>Payments:</i>		\$19,319 67
Committee on Publications . . . . .	\$4,657 32	
Committee on Library . . . . .	1,071 08	

\* Credits other than cash to the account of Committee on Publications representing the value of exchanges, books reviewed and books purchased in exchange for advertising space, aggregated \$1,504 70.

Bloomfield Moore Fund Expenditures . . . . .	519 44	
Memorial Library Fund Expenditures . . . . .	45 42	
Committee on Instruction . . . . .	1,041 86	
Committee on Meetings . . . . .	334 71	
Committee on Science and the Arts . . . . .	195 04	
Curators . . . . .	1,621 01	
Incidental Expenses . . . . .	669 36	
Salaries and Wages . . . . .	4,626 50	
Chemical Section . . . . .	117 62	
Electrical Section . . . . .	111 00	
Mining and Metallurgical Section . . . . .	56 28	
Committee on Exhibitions . . . . .	50 00	
Interest on Temporary Loans . . . . .	395 17	
Insurances . . . . .	531 89	
Committee on Building Alterations . . . . .	2,395 81	
Actuary's Petty Cash Fund (to be accounted for) . . . . .	200 00	
Contributions for Life Membership (paid to Board of Trustees) . . . . .	400 00	
Certificates of Membership . . . . .	2 00	
Scott Legacy Premium . . . . .	200 00	
		<u>\$19,239 71</u>
Balance . . . . .		\$79 96

## ENDOWMENT FUNDS.

The Permanent Endowment Funds of the Institute, at the end of 1897, consist of the following:

(In the hands of the Institute.)

Bloomfield H. Moore Memorial Fund . . . . .	\$15,000 00	
Memorial Library Fund . . . . .	1,000 00	
B. H. Bartol Fund . . . . .	1,000 00	
Amount received from Life Memberships between January 1, 1891, and October 1, 1894 . . . . .	1,755 00	
		<u>\$18,755 00</u>

(In the hands of Elliott-Cresson Trustees.)

The Elliott-Cresson Medal Fund . . . . .		4,667 68
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(In the hands of the Board of Trustees of the Franklin Institute.)

The legacy of George S. Pepper . . . . .	\$35,687 50	
The legacy of Eugene Nugent . . . . .	1,000 00	
Legacy of Mrs. Emeline B. Nicholson . . . . .	1,520 00	
The Edward Longstreth Medal Fund . . . . .	1,000 00	
The donation of an unknown friend . . . . .	5 00	
The donation of Sigmund Riefler . . . . .	20 00	
Life membership fund since October 1, 1894 . . . . .	1,050 00	
Journal Endowment Fund . . . . .	138 00	
By will of John Turner, deceased, one-fourth of net income on 2 per cent. of his residuary estate, yielding about \$100 or more per year, equivalent to a capital sum of . . . . .	2,000 00	41,520 50
		<u>\$64,943 18</u>

Total . . . . .

[An increase in 1897 of \$1920.]

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SAMUEL O. GRAYDON, M. E.	Assistant Professor of Mechanical Drawing.
ROBERT M. ANDERSON, M. E.	Assistant Professor of Experimental Mechanics and Engineering Physics.
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ALBERT R. LAWTON, A. M.	Instructor in Languages.
FRANKLIN D. FURMAN, M. E.	Instructor in Mechanical Drawing.
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For further particulars, address the President,

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# THE JOURNAL OF THE FRANKLIN INSTITUTE

DEVOTED TO

✱ Science and the Mechanic Arts. ✱

EDITED BY

MR. THEO. D. RAND, Chairman, PROF. ARTHUR BEARDSLEY, C.E.,  
PH.D., MR. JAMES CHRISTIE, DR. H. W. JAYNE, PROF. COLEMAN  
SELLERS, E.D., Committee on Publications:

with the Assistance of

DR. WM. H. WAHL, Secretary of the Institute.

*Vol. CXLV, No. 3. 73d YEAR. MARCH, 1898*

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# JOURNAL OF THE FRANKLIN INSTITUTE

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## THE FRANKLIN INSTITUTE.

*Annual Meeting, Wednesday, January 19, 1898.*

MR. JOHN BIRKINBINE, President, in the chair.

### TESTS OF THE SYNCHRONOGRAPH ON THE TELEGRAPH LINES OF THE BRITISH GOVERNMENT.

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### THE WHEATSTONE RECEIVER OPERATED BY THE ALTERNATING CURRENT IN TRANSMITTING INTELLIGENCE.

---

BY

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In April, 1897, a paper\* was read before the American Institute of Electrical Engineers, describing the general princi-

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\* The Synchronograph : a New Method of Rapidly Transmitting Intelligence by the Alternating Current.



ples of the synchronograph and the experiments at that time completed in developing it. As stated therein, the next step desirable was to test the system upon long telegraph lines having considerable distributed capacity, the length of the only line used up to that time being thirteen miles. Since then opportunity has been presented to make these trials on actual lines of considerable lengths and having different distributed capacities. Through the courtesy of Mr. W. H. Preece, Engineer-in-Chief of the British Postal System, every facility has been afforded for conducting the experiments on the telegraph lines of the British Government.

The tests were made over loops of varying lengths from the General Post Office, London, where both transmitters and receivers were located. The lines can best be used for experimental purposes on Sundays, and the tests were made on two dates, viz., August 8th and 22d, 1897, when the lines were available throughout the day. Mr. A. Eden, of the technical staff of the Engineer-in-Chief, assisted throughout these experiments, and his experience and assistance in conducting the trials were invaluable.

The apparatus available for experiment was more extensive than would usually be found in a laboratory. There was a high frequency alternator of wide range giving practically harmonic waves, from 50 to 720 complete waves per second; actual telegraph lines with values\* of  $KR$  varying from 0 to 261,000 and resistance varying from 0 to 10,000 ohms; an artificial submarine cable representing to within 1 per cent. of accuracy, an actual cable of 180 knots in length, and also the latest types of Wheatstone transmitters and receivers, with adjustable condensers, etc.

The longest loop tried was 1,097 miles, from London to Glasgow, Aberdeen, Edinburgh, and return to London by a different pole line, as indicated on the map, *Fig. 4*. This contained some iron wire and also 48 miles of underground cable, and a total value of  $KR$  equal to 261,000.

It was found in the course of trials with the different apparatus that it was possible to operate the Wheatstone receiver

\* The value of  $R$  is in ohms;  $K$  is in microfarads.

without alteration by means of the synchronograph, and a test was made over the longest line to compare the efficiency of the two transmitters when operating the same receiver under identical conditions of line. The surprising result was discovered that the synchronograph could operate the Wheatstone receiver approximately *three* times as fast as the Wheatstone transmitter on any line, provided the mechanical limit of the receiver is not already reached. The Wheatstone system

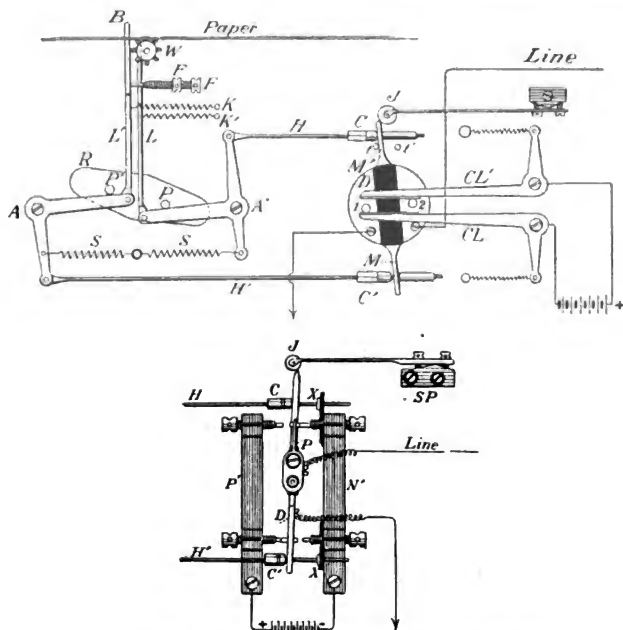


FIG. 1.—Diagram of the Wheatstone transmitter.

operated from London to Aberdeen ordinarily employs two automatic repeaters to increase the speed. Without any repeaters the synchronograph operated the Wheatstone receiver over this line practically up to its mechanical limit. By the synchronograph method of transmission it thus becomes pos-

sible to operate Wheatstone receivers at the present speeds without repeaters anywhere in the British Islands.

One of the most important results of the trials to be described has been to emphasize the probability that the sine wave possesses superiority over other forms of wave for any speed, slow or fast.

To make the experiments more clearly understood, a brief description of the Wheatstone instruments is given.

#### THE WHEATSTONE INSTRUMENTS.

For a detailed description of the latest types of Wheatstone automatic transmitters and receivers reference\* is made to books on the subject, as it is desired to direct attention in this paper only to such essential features as should be noted when a comparative test is made of the Wheatstone instruments and the synchronograph. The diagram, *Fig. 1*, indicates the arrangement of the parts of the transmitter. The messages are prepared by perforating paper tape with two rows of holes at the proper intervals to secure correct signals, one row on each side. The tape is about 12 mms. wide, and in the center, between the two rows of holes mentioned, runs an uninterrupted series of smaller holes about 1 mm. in diameter, which serve to feed the tape regularly through the transmitter. The large holes in the outer rows always come opposite a central hole. In the figure, *W* is a star-wheel which engages the central line of small holes to feed the paper, and is rotated by a weight actuating clock-work. Geared to the star-wheel is the rocker arm *R*, which therefore runs in synchronism with the wheel, so that the tape is advanced a fixed distance for every complete oscillation of the rocker. It advances from one central hole to the next for one complete oscillation of the rocker.

A characteristic of the transmitter is the fact that the contact for the electrical circuits is not made through the holes in the paper as in some transmitters; but by the small steel rods *LL'*, which pass through the holes in the paper, contacts are

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\* American Telegraphy, by W. Maver, Jr., published by Maver & Co., New York, page 296.

made and broken in another part of the apparatus by means of the levers  $AA'$  and rods  $HH'$ . For every complete oscillation of each rod  $L$  or  $L'$ , including an up-and-down motion, the battery connections are twice reversed, and as the rods move in synchronism with the paper tape, the distance between consecutive holes in the tape when continuous rows are perforated corresponds to two reversals or to one complete wave of electromotive force. The wave of electromotive force impressed upon the line by the Wheatstone transmitter is approximately represented by the broken line shown in *Fig. 2*, where the letters  $a$  and  $b$  are shown. Only the positive currents cause the receiver to make a mark. A dot together with the accompanying space corresponds to a complete wave of current. A dash with its following space occupies twice the time of a dot with its space, and corresponds to the time of two complete waves, although in reality it is a single wave with the positive portion three times as long as the negative, and thus the mark for a dash is about equal to three dots.



FIG. 2.

The chief characteristics to be noted are that the waves of impressed electromotive force are square-topped, and those for a dash are longer than for a dot.

*The Wheatstone Receiver.*—An essential part of the receiver is a polarized relay consisting of a permanent magnet and an electro-magnet. The armature, to which the recording-wheel is attached, is by this arrangement moved in one direction for a direct current and in the opposite direction for a reversed current. The small recording-wheel is kept moistened with ink, and every positive current drives it against the paper, while a negative one raises it from the paper. The paper tape is driven forward by clock-work, the speed of which is controlled by an ingenious device, and thus a series of marks is made upon the tape corresponding to the positive portions of any set of current waves. For a wave like that in *Fig. 2* there would be dots and dashes received forming the letters  $a$  and

b. By this receiver only one mark is made upon the paper during a complete wave of current consisting of a positive and negative portion. The reverse currents are not used for making marks on the paper.

The electro-magnet of the receiver consists of two solid soft-iron cores wound with spools of wire on the differential plan. To give the two coils exactly opposite magnetic effects for duplex working, the two wires are wound together as one upon the spools. The resistance of each coil is made equal to 100 ohms in the British service. They may be connected in different ways when not used for duplex working, with the coils in series making 200 ohms, or in parallel making 50 ohms for the instrument.

In practice it is found that, when connected directly to the line and the return, and operated by the transmitter, the

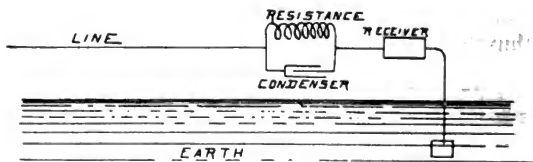


FIG. 3.

speed obtainable over most lines can be increased by the use of condensers properly arranged. The arrangement of condensers and resistance in actual use in England is indicated by Fig. 3. Common values of the resistance and capacity are about 8,000 ohms and 10 to 20 microfarads, which would vary according to the line.

#### DESCRIPTION OF THE EXPERIMENTS.

The apparatus was mounted in the experimental room in the General Post Office, London, which is conveniently wired for such tests, so that the terminals of any line can be connected to the room from the switchboards in the operating rooms above. The details of the experimental transmitter used were practically the same as those employed in the original experiments, and described in the first paper to which reference

is made. This part of the apparatus, however, was constructed specially for these experiments by Elliott Bros. of London. The messages were prepared by fastening strips of paper upon the metal surface of a large wheel geared directly to the shaft of the alternator as before described.

As it was desired to make tests over a considerable range of frequencies, the adaptability of the small Pupin alternator used in the first experiments justified cabling for this particular machine, which was loaned a second time for these trials. The alternator was driven by a 1 horse-power Lundell motor from hundred-volt constant potential mains, which were wired for the purpose from the dynamos used for lighting the building, and a storage battery was available for the excitation of the rotating field of the generator. Since the generator is in fact four alternators of 18, 22, 26 and 30 poles respectively, and the motor could be run regularly at very slow speeds as well as high, this combination with a field excitation, which could be varied at will, permitted a wide range of frequencies at any desired voltage. Transformers were used when desired. For the most rapid speeds the chemical receiver, using the same formula of Delany and operated in the simple manner described in the first paper, was employed with the synchronograph. The paper was prepared and used in the form of sheets instead of tape.

The preparations for the first trials over actual lines, which were made on Sunday, August 8, 1897, included a series of observations to determine the variations of a voltmeter of the magnetic type, with changes of frequency. For this purpose the Kelvin multicellular electrostatic voltmeter of the General Post Office was used for comparison, and observations taken over a range of frequencies from 200 to 610, and curves plotted by which any given reading of the instrument could be read as true volts. The unreliability of instruments of this magnetic type, when used for frequencies outside of that for which they are designed, is well known, and for a frequency of 610 the readings were but 73 per cent. of those of the electrostatic instrument, while for a frequency of 325 this was increased to 94 per cent., the readings coinciding at a frequency below the latter.

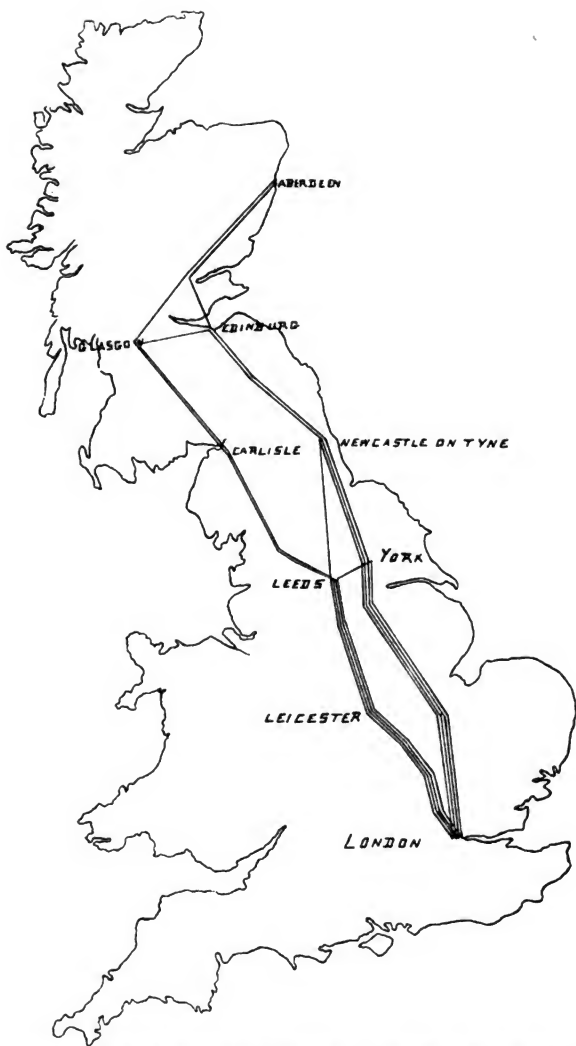


FIG. 4.—Map showing routes of lines used on August 8th and 22d, 1897.

Since the curves plotted from the observations with the electrostatic instrument proved to be straight lines passing through the origin, showing that the voltages are proportional to the speeds with constant excitation, the readings of the electrostatic instrument were probably correct.

SUNDAY, AUGUST 8, 1897.

The location of each of the four lines used is shown in the accompanying map, *Fig. 4*. The first line was from London *via* Leeds to Newcastle-on-Tyne, and return to London *via* York. The data are given in the following table:

Section.		Mileage.		R	K		Total K	K R
From	To	Open	Covered	B A Units	Open	Covered		
London	Leeds	202'88	2'83	550	3'04	'76	3'80	2090
Leeds	London <i>via</i> Newcastle-on-Tyne.	356'14	36'08	3770	5'34	9'73	15'07	56814
		559'02	38'91	4320	8'38	10'49	18'87	81518

From London to Leeds, copper wire, 400 pounds per mile; diameter, '158 inch; resistance,  $R = 2.225$  ohms per mile.

From Leeds to London, *copper wire*, 200 pounds per mile; diameter, '112 inch;  $R = 4.45$  ohms per mile; except  $82\frac{3}{4}$



FIG. 5.

miles of *iron wire*, 400 pounds per mile, diameter, '171 inch.  $R = 14$  ohms per mile.

$K$  for copper wire 200 pounds per mile = '0150 microfarads per mile.

$K$  for copper wire 400 pounds per mile = '0156 microfarads per mile.

NOTE:—The capacities given are for a line with earth connection at both ends, and when this is not the case, the circuit being a simple metallic loop, it is considerably reduced in value. When the loop is of the kind described, having the going and returning conductors separated by several miles instead



of being upon the same poles, it is seen that the total distributed capacity of the loop is approximately a quarter of its value when the earth connection is used. Let the point *A*, *Fig. 5*, represent the cross-section of the direct conductor, and *B*, that of the return, the distance between *A* and *B* being large as compared with their distance from the earth. When the line is earth-connected as represented by either diagram in *Fig. 6*, the capacity is taken from the conductor to earth all the distance around the loop; for one plate of the condenser is the whole conductor, and the other plate the earth. Let the capacity per mile when earth is used be denoted by *k*, and the length of the whole loop in miles by *m*. Then, if the total capacity is *K*, we have

$$K = km \text{ when earth-connected.}$$

If no connection is made to the earth, and the circuits are as represented in *Fig. 7*, then the capacity of the system is taken from one conductor to the other instead of to earth. Hence one plate of the condenser is the outgoing conductor *A*, and the other plate the return conductor *B*. The capacity from

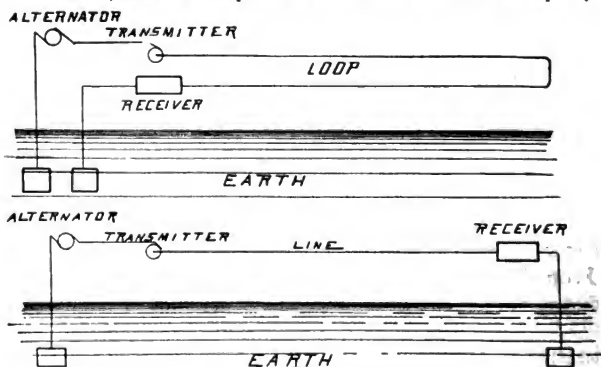


FIG. 6.

*A* to *B* when separated several miles is different from that when they are on the same poles near together. The earth is a neutral conductor comparatively near to each conductor *A* and *B* and has upon it equal charges of the opposite polarity, one kind being under conductor *A* and the opposite kind under *B*, each being equal to the charges upon the wires *A* and *B*. The capacity of the condenser from *A* to *B* is therefore equal to the capacity of two condensers in series having a capacity of *k* per mile. The equivalent capacity *K'* of condensers in series is

$$K' = \frac{1}{\sum \frac{1}{k}}.$$

In this case the condensers in series are but two in number and of equal capacity *k* per mile, hence

$$k' = \frac{1}{2} k$$

The length of one plate of the condenser is only equal to the return conductor so that the whole capacity of the loop when not earth-connected is

$$K' = \frac{k}{2} \times \frac{m}{2} = \frac{1}{4} K$$

or one-quarter of the capacity when earth-connected.

Although the capacity of the system is the same in the two diagrams of Fig. 6, the earth intervenes between transmitter and receiver in one instance while it does not in the other, and there is theoretically a difference between the wave propagation in the two cases, the velocity in the earth, however, being approximately the velocity of light. The difference is so slight that it has no appreciable effect in practice. This question has been settled by years of experience with the Wheatstone system since it is known that the speed of operation is practically the same whether the instruments be side by side or separated by the whole length of the line, provided the capacity times the resistance is the same in the two cases.

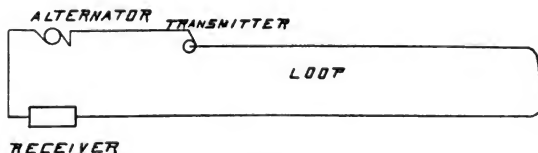


FIG. 7.

The value of  $KR$  in the line to Newcastle-on-Tyne when not earth-connected was, therefore, 20,380 instead of 81,518, and the one loop was employed as two distinct lines. When earth is used it is approximately equivalent to a line using earth return equal in length to the entire loop, and when not earth-connected it is equivalent to an actual line using earth return of half the length of the loop.

With no earth, messages were received with ease at a frequency of 652 or 1,304 alternations per second. This frequency was limited by the fact that the greatest number of poles to the generator was 30 and the number of revolutions to produce this frequency was 2,608, beyond which it was not then thought advisable to go for fear of injuring the machine.

With earth and a total value of  $KR$  equal to 81,518, a frequency of 165 or 330 alternations per second was reached.

To obtain a longer line with a greater value of  $KR$ , a second loop was made up as follows:

Section.		Mileage.		R	K		K	K R
From	To	Open	Covered	B A Units	Open	Covered		
London	Glasgow	402.72	8.74	1075	6.04	2.36	8.40	9030
Glasgow	London via Edinburgh	417.84	35.30	4185	6.24	9.52	15.76	65956
		820.56	44.04	5260	12.28	11.88	24.16	127082

*Route.*—London *via* Leeds to Glasgow, and return *via* Edinburgh, Newcastle-on-Tyne, and York to London.

London to Glasgow 400 pounds per mile, copper wire.  $d = .158$  inch.  $R = 2.225$  ohms per mile.

Glasgow to London, 86 miles of copper wire, 100 pounds per mile,  $d = .079$ ;  $R = 8.90$  ohms per mile; 47 miles of iron wire 450 pounds per mile;  $d = 0.181$ .  $R = 12.0$  ohms per mile.

As before through this line without earth,  $KR$  being 31,771, a current was sent having a frequency as high as safety to the alternator permitted, viz., 652 complete waves per second, and no limit of speed due to the line was reached, the messages being received with perfect clearness. With earth and  $KR = 127,082$ , no records were received at all on this date on account of not having at hand a suitable transformer to produce high enough potential at the slow speed of the alternator necessary. Before the next trials were made a suitable transformer was available to deal with a value of  $KR$  much larger than the above.

To test the fact that the messages were actually passing through Glasgow, and that the records were not being caused by leakage currents across the line at some point, an experiment was made of breaking the circuit by the operator at Glasgow at a certain time and restoring it again five minutes later. Before and after the line was so broken the messages were transmitted readily, while during the time it was broken not the slightest record could be obtained.

An instructive experiment, illustrating forcibly the influence of increase of distributed capacity upon aerial wires, was that of suddenly plugging in and out the earth connection,

thereby practically changing the length of the line two-fold, when at the instant the earth was connected the motor would slow down and labor under the increased load.

#### THE SYNCHRONOGRAPH AND WHEATSTONE RECEIVER.

On Thursday, August 12th, it was decided to try the synchronograph with the Wheatstone receiver, which was at hand in the same room. This was done, and without any alteration of the receiver whatever it responded readily to each wave of current from the alternator. Messages were then correctly transmitted and received. This was done by two different methods. First, the messages were interpreted by the portions of current omitted, as described in the former paper, the omission of a single mark denoting a dot and two marks a dash, the marks themselves meaning spaces. Second, the presence of the marks was used for dots and dashes, and one mark denoted a dot while two or three consecutive marks denoted

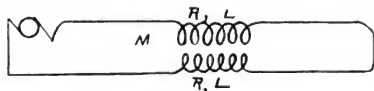


FIG. 8.

a dash. The marks are all regularly spaced, and the eye experiences no difficulty in reading the dash, even though it is made up of two or three separate consecutive marks instead of a single long mark, since the length of the dash is of more moment than the continuity of the mark.

These preliminary tests developed the fact that messages could be received by the Wheatstone receiver in the laboratory faster with the synchronograph than with the regular Wheatstone transmitter. When this discovery was made the Engineer-in-Chief desired to make a more extensive series of experiments and try the synchronograph with the Wheatstone receiver over actual lines having a value of  $K R$  sufficient to reduce the speeds. As the Wheatstone receiver was to be used with the alternating current, the first thing wanted was a knowledge of its constants. The inductance of the instrument measured by the impedance method was found to be .875 henry for a single coil and 3.46 henrys for the coils in series.

When the coils were connected so as to give opposing magnetic effects the measurements gave an inductance of .187 henry. The two coils of the receiver are wound together, the two wires being wound as one upon the spools in such close proximity that the mutual induction between the coils is at its maximum, and is nearly equal to the inductance of each coil. In such a case the inductance of the two coils in series should equal four times that of a single coil if there were no magnetic leakage, and when connected in opposition the inductance would vanish. This agrees approximately with the measurements when allowance is made for small magnetic leakage.

$$\frac{1161.9}{1137.5}$$

One Coil

FIG. 9.

Resistance 200

Impedance  $\sqrt{R^2 + L\omega^2} = 4554.4$

Reactance  $L\omega = 3.46 \times 1300 = 4550$

Two Coils in series to assist

FIG. 10.

$$\frac{316.7}{203}$$

Two Coils in series to oppose

FIG. 11.

$$\frac{1138.6}{1137.5}$$

Coils in parallel.

FIG. 12.

The circuit is represented in *Fig. 8* where the two coils of the receiver are represented in series and also in mutual relation.

When the receiver coils are connected in parallel the inductance is practically the same as that of a single coil, since the two coils are like a single one having larger wire, the number of turns being identical.

*Figs. 9, 10, 11 and 12* illustrate the relations between the impedances, resistances and reactances of the Wheatstone re-

ceiver coils when connected in different ways. *Fig. 9* is for a single coil alone, *Fig. 10* the two connected in series to assist, *Fig. 11* in series to oppose, and *Fig. 12* in parallel, each being drawn for a frequency making  $\omega = 1,300$ .

An inspection of the diagrams shows that in every case, except where the coils are in series to oppose, which would never be practicable because there is then no magnetization developed, the reactance is many times larger than the resistance of the coil. In the cases when they are in series or in parallel it is 22.75 times as much, and for the single coil 11.375.

When the receiver is used with reversing currents, such as are employed in the Wheatstone system, or with alternating currents, the impedance is the important element, and the value of the resistance makes very little difference, provided it bears so small a ratio to the impedance. If the coils of the

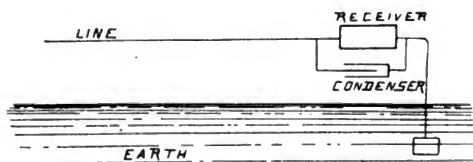


FIG. 13.

Wheatstone receiver are increased to 400 ohms, for instance, instead of being 200 ohms as at present, the impedance would only be increased about 13 ohms or  $3\frac{1}{2}$  tenths of 1 per cent.

It is found in practice, as above mentioned, that better results are obtained by the use of condensers, as indicated in *Fig. 3*. Instead of shunting the condenser directly around the receiver, however, a large resistance is first inserted in series between the receiver and the line and then the condenser shunted around this resistance. This inserted resistance is often larger than the impedance of the receiver. The reason for this particular arrangement of circuits seems to be that the waves have different lengths and the square-topped wave of electromotive force is used.

When the synchronograph was used with the Wheatstone receiver this resistance with its shunted condenser was removed

from the line and the condenser shunted directly around the receiver, as seen in *Fig. 13*.

The receiver and condenser thus form a resonant circuit, and by properly choosing the condenser it is possible to increase the receiver current materially, making it larger than the line current. This is the benefit of using a condenser, but the capacity for the best effect should vary with the frequency of alternation. By knowing the inductance of the receiver and the frequency, the condenser capacity can be calculated by the formula

$$C = \frac{1}{L\omega^2},$$

where  $C$  denotes the capacity of the condenser,  $L$  the inductance of the receiver, and  $\omega$  is  $2\pi$  times the frequency. The value of the capacity for any frequency is not very critical, that is, a condenser will improve the working for a considerable range of speed.

At present the speed of operation of the separate Wheatstone transmitters is under the control of the operator, and is independent for each instrument. In London the speed of operation of each operator is noted daily, and if found to be below a certain required limit an explanation is required from the operator. With the use of the synchronograph it is practicable to operate a number of transmitters from the shaft of one alternator, and it may be so arranged that the speeds are fixed beyond the control of the operator.

#### THE SPEEDS OBTAINED BY THE WHEATSTONE SYSTEM.

The present perfection of the Wheatstone system is much superior to that obtained with the original instruments. This improvement is due to Mr. Preece, who has gradually increased the speed from one or two hundred to six hundred words per minute. The Wheatstone system has been in commercial operation for so long a period that the speed expected on any given line is accurately known, and may be represented closely by an equation of the form

$$K R W = \text{a constant},$$

where  $K$  denotes the total distributed capacity of the line,  $R$  the total resistance, and  $W$  the number of words per minute. This constant depends upon the kind of line used, and differs

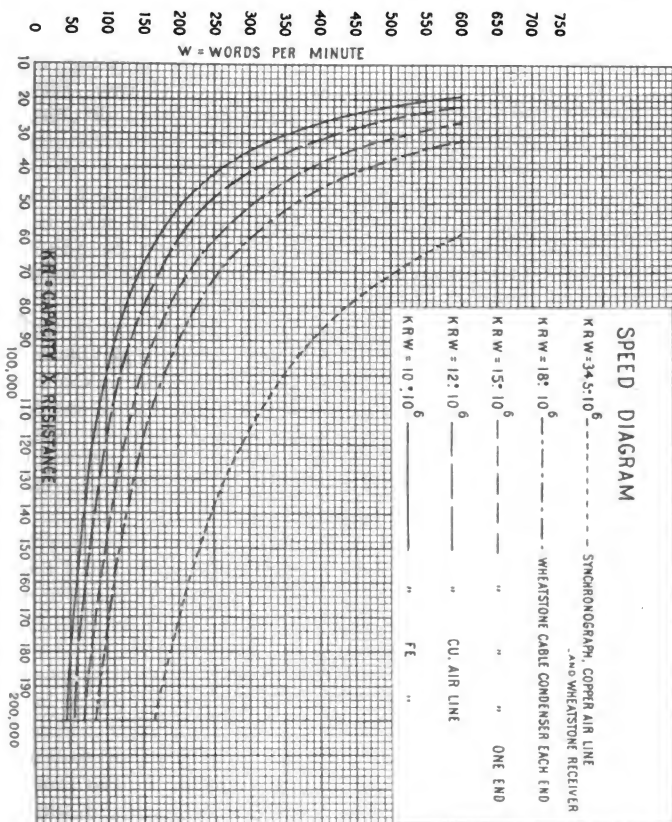


FIG. 14.

for iron and copper wire and for cables. The values of the constants determined by a series of experiments extending over a long period are



$10 \times 10^6$  for aerial line of iron wire.

$12 \times 10^6$  for aerial line of copper wire.

$15 \times 10^6$  for submarine cable with condenser at one end.

$18 \times 10^6$  for submarine cable with condensers at both ends.

These equations are exhibited in graphical form in *Fig. 14*, where the values of  $KR$  are abscissæ and  $W$  ordinates. With these variables the curves become equilateral hyperbolas, having the axes as asymptotes. There is one curve given for each of the four constants above, representing different kinds of lines. It is to be noted that all the curves terminate at the limit of 600 words per minute, as this is found to be very near to the mechanical limit of operation of the receiver due to the inertia of the moving parts, the spattering of ink or other causes.

A copper aerial line having  $KR$  equal to about 30,000 will reduce the Wheatstone speed to about 400 words a minute; and when a line exceeds this it is customary to insert an automatic repeater, by which the speed is maintained over longer distances. Speeds of 400 words a minute are regularly maintained in England in commercial working, while the limit of the commercial working in the United States is considerably lower, about 200 words per minute.

A fifth curve is added in *Fig. 14* to represent the speeds obtained with the Wheatstone receiver when operated by the synchronograph. The ordinates of this curve are about three times those of the corresponding ones for copper air line for all values of  $KR$ .

A curve for the synchronograph and chemical receiver might be given which would lie above any curve shown because of the shorter code permissible with this receiver. There would then be no limit at 600 words due to the mechanical construction, so that the curve would extend up into thousands of words per minute. The curve is not shown, because the experiments have not yet established the law of speeds for this combination of instruments.

[To be concluded.]

## THE SEVERY IMPRESSION PROCESS.

---

BY MELVIN L. SEVERY, BOSTON, MASS.,  
Member of the Institute.

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It is with a feeling of especial gratification that I am able to bring before an institution so imbued with the spirit of its founder, a matter which, were he here to-night, could hardly fail to interest him, so intimately does it seem to bear upon an industrial art which touched him very closely. As his representatives, I take great pleasure in describing to you a new method of printing, known as "The Severy Impression Process."

Historically speaking, it is but yesterday that the Leibnitz theory of innate ideas enjoyed widespread credence. To-day, happily, we have mostly outgrown this hypothesis, but we find something akin to it still surviving in the popular, and I regret to say, legal, view of the genesis of inventions. We are told about the relation of invention to intuition—how a new inventive idea is, as it were, a detached flash of genius without traceable origin, and other vague metaphysical means are brought to bear upon us in the attempt to convince us that invention bears no especial relation to logic or the reasoning faculties. This view of the matter seems to be about worthy to rank with the Platonic hypothesis of an archetypal world which has for so many centuries stifled genius in academic art. In briefly explaining the evolution of the printing process in question, I shall also be putting before you what I regard as the almost invariable method which invention pursues.

I had invented a biological game to be played with cards, each of which had a cut of an animal and descriptive matter. This game was placed in the hands of a Boston printer to publish, and when I came to correct the proof I was repeatedly asked to wait, for the reason, as I was told, that there had been difficulty in "bringing the form up." This phrase did not convey to my lay mind any definite idea, and on one occasion, when I was told that the delay was caused by inability to "make it ready," I asked, in despair: "What do you mean by

'make it ready?'" "Come out and see," was the laconic reply, and I was led into the press-room. I found there imperfectly printed portions of my game, with map-like marks in blue pencil, and upon these cards men were diligently pasting tissue paper, which they cut to form very carefully with a knife. This, I was told, was "make-ready," and it was my first acquaintance with the term. It was explained to me that every plate or type-form was uneven, some portions being higher than others, and this pasting on of paper was for the purpose of opposing on the tympan sheet (which is to say, under the sheet of paper to be printed upon) a valley to every mountain in the type-form or plate, and *vice versa*. I learned later upon inquiry that this "make-ready," as it was called, represented upon the average more than 50 per cent. of the total cost of press-work. It was an entirely novel experience to me, and I remarked to the printer then and there that there ought to be a better way of doing that, and I believed I could discover one. He replied that he would rather have a substitute for make-ready than any printing business in the world, but that efforts had been for many years made in that direction only to fail in every case.

Thus stimulated, I set to work. The first thought that occurred to me after some weeks of study was along the line of a pneumatic, or, still better, a hydrostatic cushion of peculiar construction. This, I reasoned, would give an equality of pressure all over a plate or form, and this pressure could be regulated to a nicety by a specially devised diaphragm and adjustable spring. Several hundreds of dollars were spent upon devices of this character, which were put upon a job press and tried. The result of these tests was the justification of the theory of equality of pressure, but the introduction of another factor not counted upon. It was found that when a portion of the plate was pressed into the cushion, the result was that the cushion, by the displacement of its contents, was forced down into all the unsupported or low places of the form; in short, that the printing of type had a tendency to force the diaphragm down between the type in a way to print in some cases the quads and furniture.

There seemed to be but one way of preventing this, and that was by using furniture and quads as high as the type, and preventing their printing by keeping the ink off of them by what is technically known as a "frisket," which is a sheet of paper which comes over the form just before the ink rollers pass over it and which is cut away over such portions of the form as are to be inked and printed. The necessity of such a "frisket" presented in the mind of the printer who was assisting in the performance of the experiments a very great obstacle to the success of the process, so much so that he laid the matter before the head of a printers' supply house. This gentleman said, in effect: "If you can do away with make-ready, don't be afraid of either type-high furniture or the necessity of a frisket, for such is the trouble and expense of make-ready that printers will gladly accept your process in spite of such drawbacks." This was reassuring, but it did not tell us how we were to use a frisket for the middle of a totally inclosed area, as, for example, a column of matter with a rule around it. What mechanician is there who has not at some time or other had a similar desire to connect one part of a machine with another across a line cut by a moving portion of his mechanism? Clearly the frisket in such cases, and they were very numerous, had to be abandoned, and it was, therefore, apparent that the pneumatic or hydrostatic cushion was not a satisfactory substitute for make-ready. It fulfilled its promise of equal pressure, but in doing what was expected of it at *one* portion of its area, it was made to do something else at *another* portion, which was not at all desired.

A great scientist has said that one often learns more from the experiment which fails than from the one which succeeds, and this was to some extent true in this case. I learned from this failure the requisites of proper printing, viz.: equal pressure per unit of area, which I approximately got in the hydrostatic cushion, and *independency of action*, which I conspicuously did *not* get, and the failure in the attainment of which rendered the results unsatisfactory.

How then to get this independency of action. That was the desideratum, and was arrived at by the following reason-

ing. If I thought I could get columns of molecules which would be obliging enough to yield longitudinally without affecting their juxtaposed neighbors, I should have what I want. Fluids could be made to yield readily, but not independently. If I couldn't get cake, I reasoned, I must take smelts, and as molecules wouldn't oblige me as I could have wished, I thought that pins with a spiral spring around each of them and capable of reciprocating in a backing would be the nearest approach to what was wanted. A second's consideration of this showed that it would be too coarse in arrangement, and too expensive in construction to meet the demands. The springs would be in the way and prevent the pins from being put close enough together.

The next step of reasoning was to discard the springs, make the pins themselves springs and set them closely together in a backing. The invention was beginning to crystallize. I had a bristle brush made of special design and did very creditable work with it. One very gratifying thing was sure, it was entirely independent in action in its various areas, for no one bristle had any possible means of knowing what another one was doing. Then arose the question of durability and a minor question of the uncertainty of the direction in which straight bristles would bend when pressed endwise. These questions were met by substituting for the bristle a tempered steel wire on the one hand, and upon the other giving to this wire a very slight curve to determine the direction of its flexure when pressed. All this was not arrived at in the time it takes to tell it. Much experimentation was necessary to determine the exact bend of the wire, the angle, the number of wires to the square inch, the size and temper of the same. Machinery had to be imported from England, taken down and altered over to weave this fabric, and other machines had to be devised to test it for wear and for its resistance to pressure. It should not for a moment be thought that this fabric, or any particular fabric, was the cardinal point of the invention, for such is not the case. It is the *multiplicity of independently yielding points, however arranged or of whatsoever material constructed*, that is the real essence of the invention. Tapering bristles, whether

of *rubber, fibre or hair, wire points*, howsoever arranged; in fact, all things having many independently yielding points, come easily within the scope of the invention. Each point of this fabric, and as at present constructed there are from 700 to 900 in each square inch, may be likened to a separate, automatically adjustable little platen, bent upon finding a portion of the plate, whether it be high or low, and pressing it with a definite pressure.

This brings us to a peculiarity of the fabric as at present constructed, which might easily be overlooked. It is this: The wires are slightly bent so that they may not "bunch" when they are flexed, and this bend is made *very slight*, so that each wire may give its greatest resistance when *first pressed*. In this way it will be seen that increased depression into the fabric *does not give increased impression*, or to put it another way, the high portion of the plate which touches the fabric first and is pressed farthest into it, does not encounter from the wires any greater resistance than the lower portions, for the reason that each wire gives its *greatest* resistance when *first pressed*, and then merely gets out of the way to allow the low places to come up. This fact is of the greatest moment in half-tone work, where a variety of pressures so mar the intended result that the plate is entirely at the mercy of the printer.

In the process under consideration this is not so, the individuality of the printer being entirely eliminated in all except the matter of inking, and the personality of the original artist mechanically recorded upon the paper as it is upon the half-tone plate. A few words will make this point clear: A half-tone plate is made by photographing an object through a screen, with the result that the light is diffracted in a way to leave the plate when etched composed of dots equidistant upon centers, but of every conceivable size, from a pin-point-area to large dots, practically coalescing with their neighbors to form a continuous solid. There is nothing else in the picture but these dots, and it will readily be seen, therefore, that justness of gradation of light and shade depends absolutely upon reproducing each of these dots of *just the size intended*.

The moment a sheet of tissue make-ready is placed over a section of a picture, the tendency is to give that part more pressure than other parts, and its dots are driven somewhat into the coated paper, and are materially enlarged, thus destroying all relativity of values intended by the original artist. It is in this way that a Bouguereau finds modeling in half-tone reproductions of his work taken from the originals which makes his artistic soul mutter anathemas deep, if not loud. Where is the subtlety of his carnations? Where the wonderful delicacy of his fugitive tones? Where the shimmering texture of breathing flesh? Where the marvelous consistency of his lighting that makes all parts of his work hang together like a string of pearls? It is gone, and there is little left but brutality, woodenness, false gradations, bad anatomy and a general pot-pourri of light and shade; and all this is brought about by nothing more nor less than altering, by variety of pressure, the sizes of these little insignificant dots. I do not mean to say that the results are always as bad as this, but when they are not it is due either to accident, or to the fact that the man who makes the cut ready is himself sufficiently versed in art and anatomy to know what is wanted.

Printers are wont to take the attitude that they are *themselves* the artists, and the real makers of the cut, but this hardly makes their position less deplorable, since what the *public wants* is the *personality* of the artist who creates the *original*. The business of the printer should be to suppress his personality and publish that of the artist, and this would not of necessity be accomplished were he always, what he almost never is, a great artist himself. How, think you, would Munkacsy relish having his work made ready by a Fuller who would insist that every one of his brilliant, firm tones should be viewed as through a mist? Set Corot to making ready Doré, and what would be the result?

The process we are considering mechanically justifies the plate, the plate mechanically justifies the picture from which it was photographed, and the artist's personality reaches the public pure and undefiled. The printer making ready by the old process is not to be blamed for all the shortcomings inher-

ing in the results. The chances are a hundred to one that he has never seen the original. Everything must be done empirically. Having decided in his own judgment how light the cheek of a figure should be, he has not in the least determined the degree of light that should be given to an arm. Every *feature* of a picture is *separately at his mercy*, and even if his taste be perfect, the mechanical difficulty of correlating all the features into just relations with each other is, to say the least, very considerable. By the new process the pressman finds a portion of the plate which has been burnished, and he knows that this part is to be printed in full color. He adjusts his ink and his pressure so as to get the color full on this one portion, and then *every other portion must* be right, even without the trouble of his looking at it, since the new process, with its equality of pressure, never meddles with gradations of tone. In short, it prints every dot in a half-tone of the exact size intended, never pressing the plate hard enough to drive the dots into the paper and so enlarge their impression.

What has been said about the justification of gradations in half-tones is, of course, equally true in type and all other grades of work. If the inking be properly done, the new fabric is sure to print type with that evenness of color which is by the old process so difficult to get.

Another very radical departure of the new process is in the matter of wear of type and plates. As at present constructed, presses are capable of rock-crusher pressure. The press upon which this fabric is shown has at its side-arms a crushing strength of over 150 tons, and its maker says he will warrant it to work steadily with 45 tons pressure inside the chase. Let us consider what this means to type and plates. Here, we will say, is a form of uneven type. A single type stands higher than the rest, and so invites the entire 45 tons pressure, since nothing else can be reached until this type is broken down or longitudinally compressed. Forty-five tons upon a single type! Now consider what would happen by the new process. The fabric which you will see to-night has a resistance of 112 pounds to the square inch. Suppose the high type to be a large one of  $\frac{1}{8}$ -inch printing surface. In the former case 45



tons are brought upon it, if not previously crushed; in the latter case only the strength of those wires opposite to it, and, as it is  $\frac{1}{8}$  inch square, and the fabric has a resistance of 112 pounds per square inch, it would have to stand less than 2 pounds pressure instead of 45 tons. The ratio of strain is that of less than 32 ounces to 45 tons! Is it any wonder that type seem nominally indestructible by the new process, when you consider that they can never be pressed anywhere near the point at which the molecules of their metal flow.

A test made to illustrate the relative wear of plates by the old and new process showed the following results: Fifteen sets of plates were broken down in printing an edition by the old process, while a larger edition was done by the new process upon a single set of plates, the work being of very much higher grade, and the plates were reported in good condition at the end of the run.

This increased wear will readily be seen in the case of half-tone plates by brief reference to figures. A plate made from a screen having 150 lines to the inch gives 22,500 dots to each square inch of the plate. Now since the new fabric has, roughly speaking, 800 wires to the inch, it will be seen that before the plate can be injured each wire must press 28 dots to such an extent that their metal will flow, and as 800 wires exert but 112 pounds, the maximum pressure that any dot can have is 112 divided by 800 divided by 28, or about five thousandths of a pound, which, I think, you will admit reduces the fear of injury to an absurdity; while by the old process a single dot, if it happened to be much higher than its fellows, might get the whole effective pressure of the press.

What I have said about pressure has its correlative, of course, in power with the additional fact that, since each little wire is a spring, just so much power as a job-press consumes when its jaws bite the fabric in coming together is given back to the press when the jaws separate, barring infinitesimal losses by heat and friction, which need not be considered practically. The power, therefore, necessary to run a job-press is only such as would be required to do the inking, since that requires more power than the impression would consume.

It will readily be seen that this wire fabric may be made of any desired resistance, closeness of setting, size or bend of wire. That now in use is the result of months of experimentation and is intended to have pressure enough to do the work, and yet *not* enough to even approach the danger point of type or plate resistance. There are but two things to be done in printing a plate after it is upon the press. (1) Put the ink on properly. With this the new process has nothing to do. (2) Take this ink off measurably clean by pressing a paper against the inked surface. This the fabric in question is designed to do. I am aware that printers often claim that they have to resort to a great variety of pressure to "bring out" a cut properly, and I cannot take time at present to advert to this any further than to say that if the cut is well made this position is utterly untenable in the way in which it is usually stated. Pressure should be sensibly constant per unit of area. Barring air resistance, it takes no more pressure to print period-area, when it stands in the middle of a solid and as a part thereof, than it does when it stands alone and unsupported. Solids require more pressure simply because there are more units of area.

It may not be amiss to give a moment to statistics upon make-ready. In a paper read by W. B. Conkey, before the United Typothetæ of America, on September 9, 1896 (see *American Bookmaker* for October, 1896), the records of two press-rooms are given, the first containing four job presses and nine cylinders, and the second containing twenty-two cylinders. In the first case the make-ready occupied more than 60 per cent. of the total working during 300 working days. In the second, the make-ready occupied more than 57 per cent. of the total working time during a record of 103 working days. If the make-ready for conservative figures be put at 25 to 35 per cent. of the total working time, its aggregate cost will amount to a sum of very round proportions. With the cost of printing in the United States at \$275,000,000 per annum, a process of abolishing make-ready and thereby saving more than one-fourth of the total cost of press work, should result in a very material advantage to the public. Add to this the

ease with which the fabric may be adapted to all presses, its nominal indestructibility, and the fact that it renders presses all but totally immune from accident, since loose type, or wadded paper, or similar obstructions will not, where they may be used, cause damage to the press, and its varied qualifications may be appreciated.

The ordinary layman has little conception of the great accuracy of adjustment necessary in the proper making ready of a form. Differences of a hundredth of an inch are overcome with comparative ease, it being the last ten thousandth of an inch that makes the trouble. The paper and the plate must be made to fit, not merely from the standpoint of the blacksmith, but rather that of an optician. As well might the paper be a thousand miles away from the ink as a thousandth of an inch—it either touches or it doesn't. The task of making this perfect fit of the paper to the uneven plate surface, of superimposing carefully-cut tissue paper, and even skiving its edges, is one that represents great labor, the highest skill, and is even then so uncertain a factor that the printer, unable to correctly estimate in advance, loses often all the profits calculated upon in figuring a job in this one under-estimated item of make-ready.

[At the close of his paper, the speaker made a practical demonstration of his process, which elicited considerable discussion. The meeting passed a vote of thanks to Mr. Severy for his interesting paper, and the subject was, by vote, referred to the Committee on Science and the Arts for investigation, and report thereon.]

## THE SPECIFIC HEAT OF ANHYDROUS LIQUID AMMONIA.\*

BY

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## INTRODUCTORY.

The commercial product known as ammonia consists of a solution of ammonia gas in water, in strengths varying up to about 50 per cent. The anhydrous liquefied gas, a very different article, has until recently been a chemical curiosity. Owing to the rapid development of ice-making and refrigerating apparatus in the last few years, however, pure liquid ammonia has become well known to engineers, and has been the subject of much investigation.

This substance is manufactured by subjecting the gas to pressure at a low temperature. It is a colorless liquid, having a specific gravity of about .62, boiling at  $-33^{\circ}$  C. ( $-27^{\circ}$  F.), at atmospheric pressure, giving off the suffocating vapor of ammonia. Owing to this low temperature of ebullition, the exposed liquid absorbs heat from surrounding bodies with great rapidity, a thick layer of congealed moisture settling on vessels containing it. It is sometimes frozen by the intense cold produced in evaporation. It is exceedingly dangerous to handle, producing ulcers on the skin, and even the vapor causes a painful burn. A single drop suffices to destroy the eyesight. It can be kept safely only in a strong cylinder, as its pressure at an ordinary summer day's temperature may rise as high as 200 pounds per square inch.

It has now been made practicable to reduce the amount of moisture in the liquid to an exceedingly small quantity, ordinarily to less than one-tenth of one per cent. Liquid ammonia is thus as pure a product as can be found among com-

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\* This paper was written as a thesis for the degree of Mechanical Engineer, at the Stevens Institute of Technology.

mercial chemicals, the other impurities, such as oils, etc., occurring in still more minute quantities. The manufacturers state its composition to be at least 99.9 per cent.  $\text{NH}_3$ .

#### HISTORY.

Various properties of this interesting substance have been made the subjects of experimental research by Regnault, Zeuner, Von Strombeck, Jacobus, Ludeking, Starr, and others. The heat of vaporization, specific gravity, density of the gas, specific heat of the gas, etc., are all more or less accurately known. The specific heat of anhydrous liquid ammonia, however, is a constant whose value has never been satisfactorily determined. For the last thirty years definite knowledge upon this point has been of interest and of some importance.

It is stated by Prof. De Volson Wood\* that "certain properties of ammonia have been determined by Regnault, but his determination of the latent heat of vaporization and the specific heat of liquefied ammonia were lost during the reign of the Commune in 1870."

Ludeking and Starr† also assert that "the specific heat of liquid ammonia has never been satisfactorily determined experimentally, if we except the work of Regnault. His results, however, were unfortunately lost during the Paris Commune."

It is certain that much of the data and many of the calculations of this illustrious experimenter were lost during the siege of Paris and the demolition which succeeded it. M. Debray, speaking in eulogy of his colleague before the French Academy,‡ says: "*La main brutale d'un soldat ennemi avait détruit, dans son laboratoire de Sevres, les nombreux et précieux instruments de mesure qui lui avaient coûté tant de labeurs et sans lesquels toute recherche lui devenait impossible.*"

Whether or not a determination of this quantity was ever made by Regnault, he used for the specific heat the value .799,§

\* *Thermodynamics*, p. 325. One of Regnault's latent heat determinations has, however, been found.

† *Am. Jour. Science*, III, 45, 200.

‡ *Comptes Rendus*, 86, 134.

§ *Am. Jour. Science*, loc. cit. See also *Jour. Frank. Inst.*, 130, 472.

assuming the specific gravity to be  $\cdot 76$ .\* The authority of this scientist's results is seldom to be questioned; but in the absence of his data and of a positive statement as to his having ever accomplished the work in question, various other experimenters have attempted to solve the problem.

The first recorded tests are those of Dr. Hans Von Strombeck, the records of which may be found in the *Journal of the Franklin Institute*, December, 1890, p. 467, *et seq.* He heated the ammonia, which was contained in a closed steel cylinder, in the vapor of boiling methyl alcohol circulating in a jacketed drum. The range of temperature of the liquid was from about  $62^{\circ}$  C. to  $31^{\circ}$  C., the maximum pressure in the drum being, then, about 400 pounds per square inch.

Dr. Von Strombeck's work gives evidence of great care and thoroughness; his result is not far from that obtained from theory by Zeuner.

The value given is  $1\cdot 22876$ .

A later experimental research has been made by C. Ludeking, Ph.D., and John E. Starr, C.E., and is published in the *American Journal of Science*.† The same form of apparatus—that of Regnault—was used as in the tests of Von Strombeck. The vapor of carbon disulphide was used to heat the ammonia, giving a much less excessive pressure than in the previous determination. The ratio of the masses of steel and ammonia was also better, being  $70\cdot 998$  to  $10\cdot 01$ , or  $7\cdot 1$  to  $1$ . The specific gravity of the liquid, however, is given as  $\cdot 656$ , which appears to be an error. D'Andreff's formula,‡ generally accepted, and by which Von Strombeck obtained his specific gravities, gives as the temperature of the air,  $25^{\circ}\cdot 4$  C., at which temperature, presumably, the cubic contents of the holder were ascertained,

$$\cdot 6364 - \cdot 0014 t = \cdot 6008,$$

while for the initial and final temperatures of the ammonia the value is even less than that given above.

The reported result is  $\cdot 8857$ .

\* *An. de Chim. et de Phys.*, IV, **24**, 418.

† *Am. Jour. Science*, III, **45**, 200.

‡ *Trans. A. S. M. E.*, **10**, 641.

The high reputation of both Ludeking and Starr as experimentalists caused their disagreement with Von Strombeck to leave the result, if possible, more than ever in doubt. In addition to the above values obtained by experiment, various theorists have analyzed the subject from general assumptions.

Prof. De Volson Wood calculates the value in the following way:

Assume the volume  $mM$ , Fig. 1, of the pound of liquid to be constant at all pressures, and let  $MD$  be the absolute pressure at the absolute temperature  $\tau$ ; and let  $BCS$  be the curve of saturated vapor,  $DH$ ,  $AG$ ,  $BF$ ,  $IK$ , adiabatics. Let the vapor be expanded from  $D$  at the pressure  $p$  and the temperature  $\tau$  until it is all evaporated at  $C$ , thence compressed adiabatically to  $I$ , thence at constant pressure to  $A$ , where it is liquefied, thence by abstraction of heat let the pressure be reduced to  $D$ ; then,

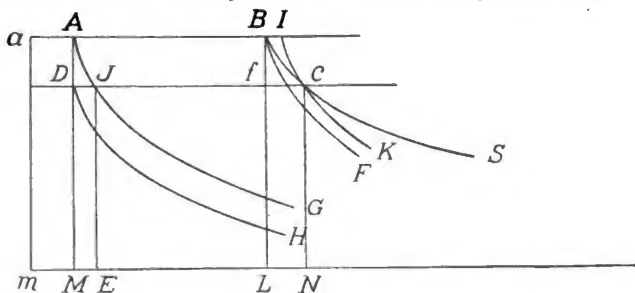


FIG. 1.

atically to  $I$ , thence at constant pressure to  $A$ , where it is liquefied, thence by abstraction of heat let the pressure be reduced to  $D$ ; then,

$$H D A G + G A I K = H D C K + D C I A \quad (1)$$

Let the temperature of  $AB$  be  $\tau + \delta \tau$ , and of  $I$ ,  $\tau + \delta \tau'$ , for the vapor from  $B$  to  $I$  will be superheated, its temperature increasing with increase of volume; then if  $c$  be the specific heat of the liquid,

$$\begin{aligned} H D A G &= J C \delta \tau & H D C K &= J h_e \\ D C I A &= v \delta p & G A I K &= G A B F + F B I K \\ h_e - h'_e &= -\delta h_e & G A I K &= J h'_e + J K p (\delta \tau' - \delta \tau) \end{aligned}$$

$$\therefore c = \frac{v}{J} \cdot \frac{\delta p}{\delta \tau} - \frac{\delta h_e}{\delta \tau} - K p \left( \frac{\delta \tau'}{\delta \tau} - 1 \right) \quad (2)$$

From the formula for the latent heat of evaporation,

$$h_e = 555.5 - 0.613 T - 0.000219 T^2,$$

$$- \frac{\partial h_e}{\partial \tau} = 0.6130 + 0.000438 T.$$

From Rankine's formula\* for the relation between pressure and temperature of a saturated vapor, representing the results of Regnault's experiments,† we have,

$$\text{com. log. } p = A - \frac{B}{\tau} - \frac{C}{\tau^2} \quad (3)$$

The value of  $C$  in this case is very small. Substituting the proper constants for ammonia,‡ we have, very nearly,

$$\text{com. log. } p = 8.4079 - \frac{2196}{\tau} \quad (4)$$

$$\frac{\partial p}{2.302585 p} = - \frac{2196 \partial \tau}{\tau^2} \quad (5)$$

$$\frac{v}{J} \frac{\partial p}{\partial \tau} = 6.49922 \frac{p v}{\tau^2} \quad (6)$$

From

$$p v = a \tau - \frac{b}{v^n}$$

the general equation of vapors, and

$$\frac{\tau}{\tau_2} = \left( \frac{v_2}{v} \right)^\gamma$$

the law of adiabatic expansion, we have, making the proper substitutions for ammonia gas,

$$p = 91 \frac{\tau_2}{\tau_2} \left( \frac{\tau}{\tau_2} \right)^{4.364} - \frac{16920}{v_2^{1.97}} \left( \frac{\tau}{\tau_2} \right)^{6.6274} \quad (7)$$

Differentiating with respect to  $p$  and  $\tau$ , changing  $\delta \tau$  to  $\delta \tau'$ , dropping all subscripts, and substituting the value of  $\delta p$  from (6), we have, by substitution in (2),

$$c = 1.12136 + 0.000438 T + \frac{p v}{\tau^2}$$

$$\left[ 6.49922 - \frac{0.50836 \times 2.3026 \times 2196}{397.13 - \frac{112135}{\tau v^{0.97}}} \right]$$

\* *Edin. New Phil. Jour.*, **47**, 235, et seq. *Phil. Mag.*, 1854.

† *Mem. de l'Acad. des Sci.*, 1847. *Comptes Rendus*, 1854.

‡ *Rel. des Exp.*, Regnault, **2**, 598-607.



As this investigation depends upon a comparatively small range of volumes, and upon assumptions with regard to the forms of the functions in some of the assumed equations, it may not be very reliable for a large range of temperatures. For  $\tau = 426^{\circ} \cdot 6$ ,  $T = -34^{\circ} \text{ F.}$ ,  $p = 1823 \cdot 7$  pounds per square foot,  $v = 20 \cdot 7985$ , we have,

$$c = 1 \cdot 093 \text{ (at } -34^{\circ} \text{ F., or } -38^{\circ} \text{ C.).}$$

A result obtained from such theoretical and empirical considerations will, at best, give only approximate results, and will be used only in case of necessity. It may never be substituted for results obtained by direct experiment, if the accuracy of the experiment is assured. The very fact that the above analysis gives a value between the two extreme experimental figures speaks in its favor. It also shows what may be considered certain, that the quantity varies with the temperature.

M. Ledoux deduces from the total heat and the latent heat an empirical expression of the form

$$A' + B't + C't^2,$$

the constants of which are calculated by means of three values taken at the extremities and middle of the thermometric scale, and previously determined by means of thermodynamic equations for the above properties. This gives for the specific heat of liquid ammonia,

$$c = 1 \cdot 0058 + \cdot 003658 t^{\circ} \text{C.},$$

which approximately agrees with Prof. Wood's analysis.

We thus have five values for the unknown quantity, viz.:

	Value.	Authority.	Temperature.
(1)	1'22876	Von Strombeck.	45° C.
(2)	1'093	Wood.	-38° C.
(3)	1'043	Ledoux.	10° C.
(4)	0'8857	Ludeking and Starr.	40° C.
(5)	0'799	Regnault.	—

There is no agreement, as the variation is greater than could be accounted for by the variation of the temperatures of the experiments. A new determination is necessary to settle

the matter. Such a new determination the writers have attempted to make.\*

In the preparations for our work, the methods and apparatus of all previous experimenters of whose work we were informed were carefully studied, including those of Regnault, Von Strombeck, Jacobus, Starr, and Ludeking.

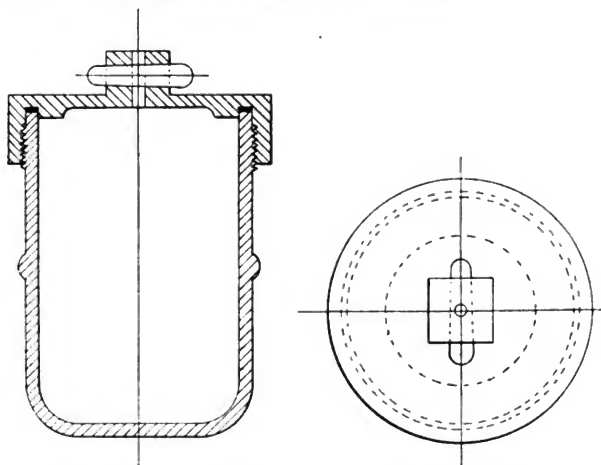


FIG. 2.—Ammonia holder.

Top view of Fig. 2.

\**Note.*—The ammonia tables given by various authorities do not agree with any great exactness. We have used the tables of Professor Wood, comparing them with those of Zeuner, and rejecting all unconfirmed values which would appreciably vary the result.

The deductions of Ledoux, given above, are explained in detail in his "*Machines à Froid*," a translation of which, by Professors Denton, Jacobus and Riesenberger, has been published in Van Nostrand's Science Series.

The calculation of Professor Wood's value for the specific heat is given in his "*Thermodynamics*," edition of 1895, p. 335.

A confirmation of the theoretical conclusions of Ledoux has been brought forward by Prof. J. E. Denton (*Trans. A. S. M. E.*, **13**, 522). In a refrigerating test, the following values for the latent heat were found, at temperatures corresponding to those given by Ledoux:

Ledoux gives (1) 583.1 (2) 528.1.

Denton finds (1) 581.2 (2) 521.0.

It is probably less than 580 B. T. U. See p. 389, Wood's *Thermodynamics*, and foot-note.

## EXPERIMENTAL RESEARCH.

The apparatus used was designed entirely by the writers, and constructed under their personal direction. It consisted essentially of an ammonia holder suspended in a closed chamber surrounded by melting ice.

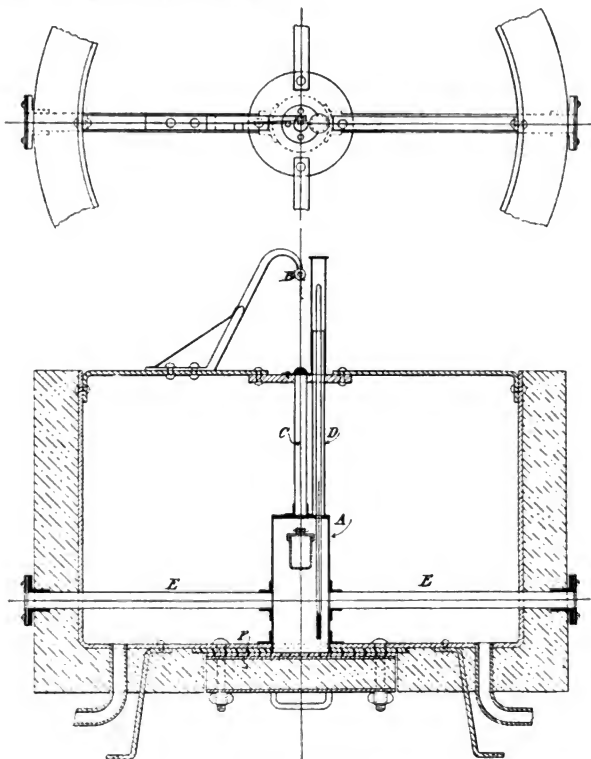


FIG. 3.—Cooler.

The ammonia holder, *Fig. 2*, was of soft steel, with an accurately ground lead washer for a bearing surface. It was turned from a solid bar, and was of a uniform thickness of  $\frac{1}{8}$

inch. The thread on the cap was made so as to be screwed without using the wrench. The use of the pin through the cap will presently be shown. It was case-hardened, ground to fit the hole, and again hardened. The cooler, *Fig. 3*, was essentially an iron tank, in the bottom of which was inserted a copper box, *A*, brazed at all joints so as to be air and water-tight. The holder was placed in this box, hanging from the hook, *B*,

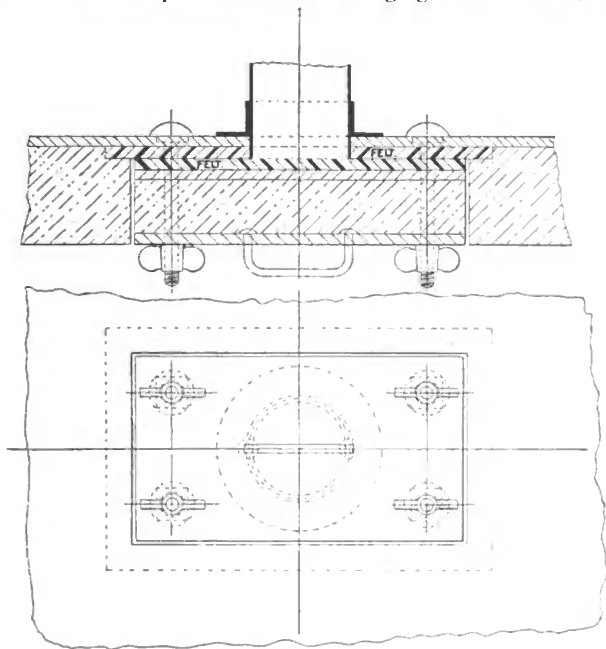


FIG. 4.—Detail of cover plate.

upon a thread which extended through the fine tube *C*. The thermometer for ascertaining the temperature of the cold chamber *A* was suspended in the brass tube *D*, and was read through the blackened sight tubes *EE* by means of a cathetometer telescope. A gas flame furnished the necessary illumination through these tubes.

Below the chamber *A* was a plate *F*, shown in detail in *Fig. 4*, which was at once air-tight and easily removable. The entire tank was coated with a 2-inch thickness of asbestos felt and canvas.

The calorimeter used was of the non-jacketed type, of copper, and had a total capacity of about 90 cubic centimeters. It was made as light as possible, in order to obtain a sufficiently large range of temperature.

The thermometers were purchased from Mr. Richard K. Green, of Brooklyn, N. Y., and were graduated to  $\frac{1}{10}^{\circ}$  C. By means of a magnifying lens, mounted in a tube so as to obviate the effect of parallax, hundredths of degrees were accurately estimated.

The balance was manufactured by Becker Brothers, of New York, and in duplicate weighings was found to be consistent within a milligram.

The ammonia used was obtained from the National Ammonia Company, of St. Louis.

[To be concluded.]

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## AN IMPROVED PROCESS AND APPARATUS FOR MANUFACTURING MOSAICS.

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*Being the report of the Institute, through its Committee on Science and the Arts, on the invention of Herman C. Mueller, of Zanesville, O.*

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[No. 1,958.]

HALL OF THE FRANKLIN INSTITUTE,  
PHILADELPHIA, August 26, 1898.

The Franklin Institute, of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of "Mueller's Process of, and Apparatus for, Manufacturing Mosaics, etc.," finds as follows:

That the invention is the subject of Letters-patent of the United States, No. 537,703, dated April 16, 1895, granted to Herman C. Mueller, of Zanesville, O., and operated on the commercial scale by the Mosaic Tile Company, of that city.

For the proper understanding of the scope and character of this invention, it will be necessary to present some historical data in connection with the development of this branch of the arts.

The earliest specimens of the art that need be considered in this report are those known respectively as the Roman and Florentine mosaics, the characters and modes of producing which are so well known as to require no explanation. Following these well-defined types of mosaic decoration, came the encaustic tiles of the so-called Italian renaissance, in which the surface of the clay slab was carved or engraved in such manner that the lines and surfaces to be executed in color in the design were sunken and then filled in with the required colored clays. After this composition had acquired sufficient hardness to permit of cutting, the tiles were finished by shaving the surface to remove the excess of colored clays, by which the design was exposed in clear and sharp lines.

A simplified method of producing tiles with designs inlaid in the surface was introduced by the English potters. This consisted in preparing a plaster mould having the design raised upon its surface. Into this mould the plastic clay is pressed, and the tile is thus obtained at once with the design sunken into the surface, without the labor of carving it out by hand. To finish the tile, however, there still remains the same laborious inlaying of the colored clays and the shaving down of the surface required in the older method.

This process is said to be still in use in England and the United States, but has the several disadvantages of being tedious of execution and expensive. It is likewise technically defective, in that the large shrinkage of a plastic-formed clay in drying and burning makes it difficult to obtain a product sufficiently true for floor use, and this difficulty becomes well nigh insurmountable when several colors are inlaid in the same piece.

In 1840, Prosser, in England, invented the process of making tiles with clay-dust or flour, by compression. This is known as the "dry-press process," and has replaced the plastic clay process for unicolored tiles.

In 1852, Villeroy and Boch, of Mettlach, in Germany, invented a dry-press method for the inlaying of colored designs with clay-dust, thus obviating the difficulties inherent in the plastic clay methods, and substantially improving upon the dry-press method of Prosser. This process, which is widely practiced in the production of inlaid designs, like the Florentine mosaics and those of the inlaid encaustic tiles, is executed in the following manner:

A cloisonné, or compartment-frame, made of thin strips of metal bent to follow the outline of the design and the different colors and soldered together, serves, upon being set in the steel die in which the tiles are to be compressed, to divide it into compartments coincident with the design.

In these compartments of the frame, set in the die, the colored clays in the form of dust or flour are carefully filled. When all the clay is in place, the compartment-frame is carefully lifted out. The design now lies in the bottom of the die, in the form of a loose powder, but each color holds the other in its exact position. To give the tile the necessary body, a coarser backing clay is sifted upon the colored inlays, until the die is filled, when the whole is solidified by heavy pressure. Upon removal of the tile from the die and reversing it, the pattern will be found upon the surface, the colors penetrating, as a true mosaic of the Florentine type.

Economical in execution and technically satisfactory as this process has proven itself to be, it suffers from the limitation imposed upon larger and particularly original designing, in the great cost of the cloisonné or compartment-frames. Thus, the production of a two-color mosaic pattern, complete upon a single tile, requires five compartment-frames exactly conforming to the design, for one press. Each frame, for a moderately simple pattern, requires for its making three days' labor of a highly skilled mechanic, a minimum cost of from \$45 to \$50, hence, designing in this art has been practically restricted to damask or diaper patterns, with repetition of the individual figure not over 6 inches or a foot square.

Considerations of cost, therefore, practically, exclude the application of this method in the case of designs of an area

involving a larger number of different tiles, and would absolutely prohibit its use in the case of original designs, which are to be used once or twice only.

We now come to the process and apparatus of Mr. Mueller, which form the subject of this investigation. The process belongs in the class of the dry-press processes, and the inventor has a simple and ingenious mechanical means of making inlaid designs of various colored clays, reproducing the form and color of any original, which affords not only a radical solution of the problem of cost by which the pre-existing methods were handicapped, but also renders possible the making of a product having unique artistic characteristics, and which gives fair promise of greatly extending the field of indestructible polychromatic paving, flooring and interior and exterior mural decoration in modern architecture.

The basis of the Mueller invention consists in part of an improved method of distributing the colored clays to the compartments of the frames by sifting the same through specially prepared stencils of stiff paper, and in part of an improved "cell-frame" for holding the body of the pulverized clays distributed through these stencils. With the aid of this improved cell-frame and the paper stencils, through which the colored clays are sifted, any design or part of a design of large area, falling on a single tile, can be executed without the use of a special cloisonné or compartment-frame, which, because of its excessive cost, limited the utility of the older method above referred to.

The scope and character of the invention will appear very clearly from the first claim of the Mueller patent, to-wit:

"The improvement in the art of producing mosaics or ornamentally surfaced tiles or entablatures, consisting in dividing the mould-space by intersecting partition walls of uniform thickness into an aggregation of open cells; removing the partitions and allowing the cell contents to rest upon the bottom of the mould and acquire lateral support against each other; and, finally, by compression of the entire aggregate mass of earth, compressing the tile in the usual manner for the finishing operations, substantially as set forth."



To illustrate the great saving in the cost of reproducing an original design by his process, as compared with the most improved method previously known and used, the inventor submits the following comparison, the accuracy of which the investigating committee does not question.

"A panel 12 feet square, showing the crest of the Count of Chambord, was exhibited at the Paris Exposition in 1889, the compartment-frames for producing which, made at the factory of Boch Frères, in Maubege, cost 20,000 francs." \* \* \*

"The preparation of the paper stencils for these designs would cost not to exceed \$15, the stencils all being used with one and the same cell-frame, which is not more expensive to make than a single cloisonné, or compartment-frame, while the making of the numerous frames required for the design cost, as stated, \$4,000. Furthermore, the making of these cloisonné or compartment-frames would require 1,800 working days of the service of a skilled mechanic, while the paper stencils for my system would only take the service of a girl for twenty working days."

"The thorough practicability of my process has been proven by its use on a manufacturing scale since the issue of the patent, in the works of the Mosaic Tile Company, at Zanesville, O., where works of very much greater dimensions than the one cited above have been executed, and that, too, for but a single application, although the process is essentially a multiplying one."

The mechanical details of the Mueller process will be clearly understood from the following description:

*Stencils.*—The design being made, it is cut into pieces, corresponding with the size of the tile to be made. As the tiles shrink in burning, the original design must be made accordingly on a larger scale. (This shrinkage amounts to about  $\frac{1}{2}$  inch to the foot). It is not necessary that the colors should be painted on the cartoon, an outline of the different colors will suffice.

With the aid of a punching machine, which transfers the design to the paper stencils to be cut, a stencil is made for every color that is to be inlaid in the tile.

*Dies.*—Tiles are pressed in steel dies, which are about  $1\frac{1}{2}$  inches deep and are open on both sides. (Fig. 1.)

*Bottom Plate.*—A bottom plate forms the foundation for the tile to be pressed, the die resting on it. (Fig. 2.)

This plate holds the metal mould on which the tiles are pressed. It must be very strong to withstand the pressure.

*Top Plate or Plunger.*—The top plate or plunger consists of a steel block, which enters the die and compresses the clay sifted in. It is also used to push the tile out, after it is pressed and after the bottom plate is removed. (Fig. 3.)

*Cell-frame.*—A cell-frame, consisting of metal strips described in what has preceded, is used to keep the colors to be sifted in in their places, according to the intended design.

*Stencil Holder.*—To give the paper stencils more stability,

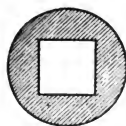


FIG. 1.

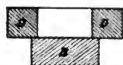
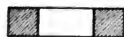


FIG. 2.

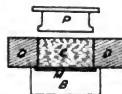


FIG. 3.

*D*, die; *B*, bottom plate; *P*, plunger; *C*, clay; *M*, metal mould.

and hold them firmly to the cell-frame while the colors are in, a metal or tin frame is used, which also protects the die from any color falling on it.

The stencil holder fits the die exactly and enters it to some extent.

*The Pressing.*—After the die is set on the bottom plate, the cell-frame is inserted, so that it rests on the bottom. This apparatus is passed to the first workman, who lays the stencil in the die and sifts the corresponding color in. This color (powdered colored clays) falls through the holes in the stencil into the small compartments of the cell-frame (which corresponds with the holes in the stencil). After the first color is sifted in, the stencil is withdrawn, the apparatus is passed to the next sifter, who repeats the performance with another color, and so on, until all the needful colors are sifted in and every compartment of the cell-frame is filled.

The cell-frame is then withdrawn and the inlaid mosaic is left lying on the bottom of the die. The backing material (powdered clay of coarser substance) is then sifted in until the die is filled. With a straight edge this clay is struck off and the plunger (top plate) is laid on the clay. The apparatus is shoved under the hydraulic press and the pressure is turned on (2,000 pounds to the square inch). After the tile is pressed and the pressure relieved, the apparatus is passed from under the press, the bottom plate is removed, the plunger is pushed further down and the tile drops from the die, ready to go to the drying-room, and thence to the kiln.

From the foregoing description of the Mueller invention, it will be apparent that it can be applied to the production of permanent floor and mural decorations from original designs of considerable sizes, without overstepping reasonable limits of cost.

The character of these reproductions is peculiar to the process, and its general effect has been compared with that exhibited by designs in woven fabrics, made upon the Jacquard loom. It is in fact adapting the principle of the Jacquard invention to the art of mosaic work.

The practicability of the process for work of considerable magnitude has already been demonstrated by the inventor, in the successful production of mural tablets, friezes, mosaic flooring, etc., and it would appear that for work on exteriors and interiors, that is to be seen at a considerable distance from the eye, the process promises to be particularly well adapted.

It will be premature to attempt, at this stage of the development of this ingenious process, to define the limits of its utility. The committee to which this invention was confided, is unanimous in the belief that the invention marks a distinct step in advance in the art to which it relates, and that it offers an admirable means of greatly extending the application of polychromatic decoration of a durable character and of considerable artistic excellence in architecture—something of which architecture of the present day is very much in need.

For these reasons, the Franklin Institute recommends the award of the John Scott Legacy Premium and Medal to the inventor, Herman C. Mueller, of Zanesville, O.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, October 6, 1897, and approved by the Board of Directors of City Trusts.

JOHN BIRKINBINE, *President.*

WM. H. WAHL, *Secretary.*

Countersigned by

JAMES CHRISTIE,

*Chairman of the*

*Committee on Science and the Arts.*

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THE ECONOMETER: A GAS BALANCE FOR INDICATING CONTINUOUSLY THE PROPORTION OF CARBONIC ACID GAS IN THE FLOW OF FURNACE GASES.

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*Being the report of the Institute, through its Committee on Science and the Arts, investigating the invention of Max Arndt, of Aix-la-Chapelle.*

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[No. 1,973.]

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, September 1, 1897.

The Franklin Institute, of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of Arndt's Econometer, reports as follows:

The sub-committee appointed to investigate the operation of an instrument for the measurement of carbonic acid gas (CO<sub>2</sub>) escaping in the flow of the products of combustion from a steam-boiler furnace, have performed the duty assigned them, and beg to report that:

This instrument is known under trade name of Econometer, and is the invention of Max Arndt, of Aix-la-Chapelle, Germany, by whom it was patented in the United States, October 16, 1894.\*

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\* See U. S. Patent, No. 527,397.

Through Mr. Joseph Wilckes, of New York City, the inventor's American representative, a request has been presented to this Institute for an examination into the merits of the instrument, for the purpose indicated above.

The apparatus consists of a balance beam, carrying at one end a gas vessel, provided with a neck open at the bottom; a gas delivery pipe projecting upward into this gas vessel being fixed and supported in it in such a way that upon the oscillation of the balance beam the gas vessel may move freely up and down without coming in contact with the upward projecting pipe through which the gas flows into the gas vessel.

The gas vessel is balanced by a compensating vessel suspended from the opposite end of the beam, also open at the bottom, and equivalent to the gas vessel in its capacity in conjunction with small weights placed on a pan under the compensating vessel, that the pointer of the beam shall move to zero on the scale when atmospheric air is drawn through the apparatus.

The gas vessel being open at the bottom, so that the pressure within it is always the same as that without, fluctuations of pressure and barometrical readings have not to be considered in the use of this apparatus, likewise fluctuations of temperature do not affect its action, because the gases passing slowly through the apparatus quickly take the temperature prevailing in the narrow gas passages.

The fluctuations which take place in the density of the gases round the fixed pipe in the gas vessel cause up-and-down motions in the latter vessel, which are shown by the pointer on the scale. This pointer is rigidly fixed to the beam so as to follow the movements of the gas balance; it oscillates in front of a divided plate or scale, indicating units of weight by the distance between its dividing lines, or these distances shall in conjunction with the pointer indicate a particular percentage volume of a particular kind of gas in a gaseous mixture. For example, the instrument placed at the disposal of this committee had divisions on its scale for indicating the percentage volume of carbonic acid gas, for the purpose of ascertaining

the percentage of such gas escaping in the products of combustion from a steam-boiler furnace.

Two tubular orifices are provided, one for the inlet, and the other for the outlet of gases, the former connecting by a flexible tube with the vertical fixed pipe in the gas vessel, and the latter by a flexible tube with the cup-shaped vessel situated below the gas vessel. The source of the gas supply is placed in communication with inlet leading to the gas vessel, and a suction apparatus of any suitable kind in communication with outlet from the cup vessel under the gas vessel. A portion of the air present in the casting is first drawn off, that is to say, the air is exhausted by suction to so much of a vacuum as corresponds to the strength of the suction at the cup vessel under the gas vessel. This rarefaction being obtained, the gas to be weighed passes into the gas vessel, filling it, and then out of this vessel into cup vessel below.

The gas balance is enclosed in a casing provided with a glass front for the purpose of observation; this casing is provided with an aperture closable by a plug, upon the removal of which the weights may be adjusted as required. Further, at the top of the casing, there is an aperture filled with cotton-wool for the gradual and continuous admission of atmospheric air thereto. The balance is, therefore, located in a nearly air-tight chamber, with its several parts so arranged that, when the gases to be weighed flow through a vessel forming part of the balance, it may operate without resistance and with greatest sensitiveness.

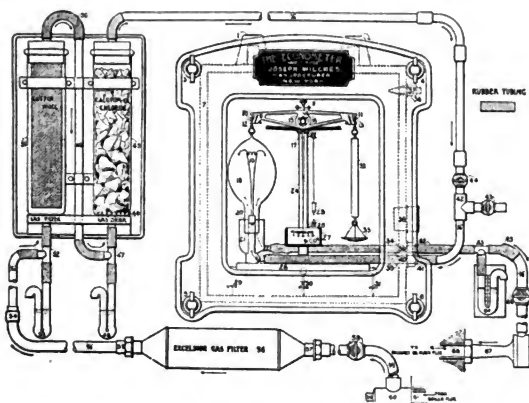
The determination of the percentage volume of a particular kind of gas contained in a gaseous mixture is only practicable by means of the apparatus when the specific gravity of the gas sought for is different from the specific gravities of the other gases preponderating in the gaseous mixture, but such other gases may be of like specific gravity among themselves. This, for instance, is the case with respect to the smoke gases of steam-generator furnaces, which gases are mainly made up of oxygen, nitrogen, carbonic oxide and carbonic acid. Of these, the first three are of nearly the same specific gravity, approxi-

inating that of atmospheric air = 1. On the other hand, the specific gravity of carbonic acid = 1.52, and is, therefore, about one-half heavier than atmospheric air, and a smoke-gas mixture must consequently be heavier the greater its contents of carbonic acid. With perfect combustion of the carbon contained in the fuel and with the air of combustion measured in a theoretically accurate manner, the carbonic acid of the smoke gases amounts to about 20 per cent. of the total volume, but it is less than this when the air of combustion is supplied in a larger quantity. If now the zero line of the scale has such a position that it coincides with the pointer when only atmospheric air is present in the gas vessel; if, further, the end line or division of the scale has such a position that it coincides with the pointer when atmospheric air mixed with carbonic acid to the extent of 20 per cent. of the total volume as determined by a chemical analysis, is drawn through the gas vessel; and if, further, the scale has twenty corresponding divisions, then the movement of the pointer from one division to another will correspond to the difference in the weight of the gaseous mixture in proportion to the percentage volume of carbonic acid; and accordingly, in the practical use of the apparatus, that is to say, when smoke gases are being conducted through the gas balance, the contents of carbonic acid, as indicated by the pointer in a sufficiently accurate manner for practical purposes, may at any time be read off from the scale direct. If, for instance, the pointer points to the division line marked 12 on the scale, this would indicate that the smoke gases drawn through the vessel contain 12 per cent. in volume of carbonic acid, that is to say, the volume of the latter would amount to 12 per cent. of the whole volume of the smoke-gas mixture.

If the smoke gases of a steam-generator furnace when passing to the chimney have a temperature of  $270^{\circ}$  C. (or  $518^{\circ}$  F.) and 12 per cent. of their total volume consists of carbonic acid, the loss of heat amounts only to about 15 per cent.; but if at the same temperature the carbonic acid contents amount, for example, to only 4 per cent. of the volume of the waste gases, this would show a loss of heat of about 45 per cent., due in a great measure to the heating of an excessive quantity of

air for the combustion of the fuel. Hence, it results that the gas balance herein described is of great importance as a controlling apparatus for steam generator and other furnaces and also for obtaining the specific gravity of other gaseous mixtures by direct weighing.

A practical test of this instrument was made by the investigating committee, at the Baldwin Locomotive Works in this city, with the results given in the annexed table. The boiler furnace from which the supply of gas was taken was one in which anthracite coal was used, the boiler was of the Babcock & Wilcox manufacture, and its furnace setting was in no re-



The Arndt "Econometer."

spect different from their ordinary practice. The gas analysis was by Prof. Harry F. Keller, Ph.D., of this city, each analysis was made immediately upon the withdrawal of the samples and at the place where the other tests were being conducted.

These comparative tests satisfied the investigating committee as to the substantial accuracy of this instrument. The recorded variations given in the annexed tables show discrepancies so trifling that, if the econometer were used in the management of steam-boiler furnace fires, no considerable loss would occur by reason of the difference between the

VOL. CXLV. No. 867.



econometer reading and the chemical analysis. A saving in fuel would result because of a better and more intelligent management of fire and damper, allowing less surplus air to pass through the furnace than would ordinarily be the case.

The "Econometer" works continuously, and shows automatically the percentage of carbonic acid in the gases, thus enabling the fireman to see at all times the more or less favorable conditions of combustion.

The claims made for this instrument have, in the opinion of the investigating committee, been fully substantiated in its presence, and the Franklin Institute therefore awards the Elliott-Cresson Medal to Max Arndt, of Aix-la-Chapelle, Germany.

An appendix accompanies this report, giving some theoretical deductions by Max Arndt, on the subject of partial combustion. Also the record of observations and gas analysis relating to the test at the Baldwin Locomotive Works.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, October 6, 1897.

JOHN BIRKINBINE, *President.*

WM. H. WAHL, *Secretary.*

Countersigned by

JAMES CHRISTIE,

*Chairman of the*

*Committee on Science and the Arts.*

#### APPENDIX.

The following table, accompanying the description of the "Econometer" furnished your committee, shows the loss of heat and fuel with from 2 to 15 per cent. of carbonic acid gas in the combustion gases:

For coal of medium quality.	If the "Econometer" shows . . . . .	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Per cent. carbonic acid.
	Then the quantity of air passing through the flues is . . . . .	9.5	6.3	4.7	3.8	3.2	2.7	2.4	2.1	1.9	1.7	1.6	1.5	1.4	1.3	Times the theoretical requirements.
	With a surplus supply of air of 30 per cent., or about 10.4 cubic metres of necessary air per kilo. of fuel, there will still be a further excess of about . . . . .	65.6	40.0	27.2	20.0	15.2	11.2	8.8	5.6	4.8	3.2	2.4	1.6	0.8	0.0	Cubic metres of superfluous air, heated to a temperature of usually 270° C.
	And the loss of fuel at 270° C. amounts to . .	90	60	45	36	30	26	23	20	18	16	15	14	13	12	Percent.

One kilogram of anthracite coal of medium quality requires theoretically about 8 cubic meters of atmospheric air.

If, for example, in the case of a steam boiler using a medium quality of anthracite, the econometer shows an average of only 3 per cent CO<sub>2</sub> (a case often happening in practice), then the volume of air used for the combustion of a kilogram of coal and the almost equal volume of gaseous smoke is about  $8 \times 6.3 = 50.4$  cubic meters reduced to the temperature of 0° C.

If the atmospheric air passes to the grate at a temperature of 20° C., and the combustion gases leave the boiler at 270° C., the difference of temperature amounts to 250° C., then the heat carried away by the chimney gases (which, on an average for each degree centigrade per cubic meter, require 0.32 of a heat unit) amounts to  $50.4 \times 250 \times .32 = 4032$  heat units.

Further, if the anthracite coal used has an actual heat value of 7,000 heat units, the loss of heat or fuel loss can be calculated at about

$$\frac{4,032 \times 100}{7,000} = 58 \text{ per cent.}$$

If with the same firing and with a larger supply of air the amount of carbonic acid falls to 2 per cent., the loss amounts at once to  $8 \times 9.5 \times 250 \times 0.32 = 6080$  heat units, or about

$$\frac{6,080 \times 100}{7,000} = 87 \text{ per cent. of coal.}$$

## RECORD OF TEST OF ECONOMETER AT BALDWIN LOCOMOTIVE WORKS, AUGUST 13, 1897.

Time.	Econom't'r Reading.	Gas Analysis.			Draft M'm.	Memoranda.
		Sample Taken.	Carbonic Acid.	Oxygen.		
P.M.	Per Cent.	P.M.	Per Cent.	Per Cent.		
2.04	3'80					Fired at 2 P.M.
2.05	3'80	2 05	4'02	14'95		Steam pressure 135 pounds.
2.05½	3'80					Fire about 7 inches thick.
2.06	3'80					
2.06½	4'00					
2.07	4'00					
2.07½	4'00					
2.08	4'10					
2.08½	4'10					
2.09	4'00					
2.09½	4'00					
2.10	4'00					
	3'95				7 m.m.	
	Average.					
2.21	4'70	2.21	4'84	no det.		
2.21½	4'70					
2.22	4'70					
2.22½	4'65					
2.23	4'15					
2.23½	3'40					
2.24	3'15					
2.24½	3'10					
2.25	3'30					
2.25½	3'40					
	3'915					
	Average.					
2.40	3'80					
2.40½	3'80					
2.41	3'90					
2.41½	3'90					
2.42	3'90					
2.42½	4'00	} 2.43	4 12	15'46	7 m.m.	
2.43	3'90					
2.43½	3'90					
2.44	3'80					
2.44½	3'80					
2.45	3'70					
2.45½	3'60					
2.46	3'50					
	3'81					
	Average.					
3.00	8'00					Fired 2.49 P.M.
3.00½	8'00					Steam jet blower on at 2.54 for 5 minutes.
3.01	9'10					Fired 3 P.M.
3.01½	9'40					
3.02	9'60					
3.02½	9'70					
3.03	9'00	} 3.03	9 06	10'85	7 m.m.	
3.03½	7'00					
3.04	6'80					
3.04½	7'20					
3.05	8'00					
3.05½	8'60					
3.06	8'90					
3.06½	9'00					
3.07	8'90					
	8'52					
	Average.					

## RECORD OF TEST OF ECONOMETER AT BALDWIN LOCOMOTIVE WORKS, AUGUST 13, 1897.

Time.	Econom'tr Reading.	Gas Analysis.			Draft M'm.	Memoranda.
		Sample Taken.	Carbonic Acid.	Oxygen.		
P. M.	Per Cent.	P. M.	Per Cent.	Per Cent.		Blower on 3.15 P. M.
3.23	11 00					
3.23½	11 00					
3.24	10 90					
3.24½	10 80					
3.25	10 50					
3.25½	10 50	} 3.26	10 53	8 38	8 m.m.	Fired 3.26 P. M.
3.26	10 40					
3.26½	10 30					
3.27	10 10					
3.27½	9 80					
3.28	9 70					
3.28½	9 60					
	10 38					
	Average.					
3.40	8 70					
3.40½	8 60					
3.41	8 50					
3.41½	8 70					
3.42	8 40					Blower off 3.42 P. M.
3.42½	7 90	} 3.43	6 57	not det.	7 m.m.	Fired 3.44 P. M.
3.43	6 80					
3.43½	6 00					
3.44	5 50					
3.44½	5 10					
3.45	4 80					
3.45½	4 60					
	7 02					
	Average.					
3.54	4 00					
3.54½	4 00					
3.55	4 00					
3.55½	4 00					
3.56	4 10					
3.56½	4 30	} 3.57	4 38	15 10		
3.57	4 50					
3.57½	4 40					
3.58	3 80					
3.58½	3 30					
3.59	3 00					
3.59½	3 10					
4.00	3 50					
4.00½	4 00					
	3 857					
	Average.					

[NOTE.—The "Econometer" readings inclosed in braces are those taken during the time of drawing the samples for chemical analysis.]

# GRAPHICS OF THE THERMODYNAMIC FUNCTION.

BY WILLIAM FOX,  
Assistant Professor of Applied Mathematics.

On reading Professor Thurston's article on the "Graphics of Thermodynamic Law,"\* I thought that it might interest students of the subject to see that graphics can be applied even to the mystical function  $\phi$  and to all theorems depending on it.

We start with equation (9) of Dr. Thurston's article:

$$dH = K_v dt + t \frac{dp}{dt} dv \quad (1)$$

From the "defining" equation of a gas,  $p v = R t$ , we readily obtain

$$p \left( = t \frac{dp}{dt} \right) = \frac{R t}{v} \quad (2)$$

and hence

$$dH = K_v dt + R t \frac{dv}{v} \quad (3)$$

and

$$\int dH = K_v \int dt + R \int t \frac{dv}{v} \quad (4)$$

which can be solved only when we know the law of variation between  $t$  and  $v$ , or when either  $t$  or  $v$  is constant.

Dividing equation (3) by  $t$ , we get

$$d\phi = \frac{dH}{t} = K_v \frac{dt}{t} + R \frac{dv}{v} \quad (5)$$

and

$$\begin{aligned} \phi &= \int \frac{dH}{t} = K_v \text{hyp. log. } t + R \text{hyp. log. } v + C \\ &= \text{hyp. log. } (t^{K_v} v^R) + C \\ &= \text{hyp. log. } (t v^{\gamma-1})^{K_v} + C \end{aligned} \quad (6)$$

\* Jour. Frank. Inst., 141, 27.

The quantity  $\phi$  may also be expressed as a function of  $p$  and  $v$ , or of  $t$  and  $p$ :

$$\varphi = \text{hyp. log.} \left( \frac{p v^\gamma}{R} \right)^{K_v} + C \quad (7)$$

$$\varphi = \text{hyp. log.} \left( R^{\gamma-1} \frac{t^\gamma}{p^{1-\gamma}} \right)^{K_v} + C \quad (8)$$

As is well known,

$$R = K_p - K_v = \left( \frac{K_p}{K_v} - 1 \right) K_v = (\gamma - 1) K_v = a p_0 v_0$$

By means of equations, 6, 7, 8,  $\phi$  can be found if any two of the quantities  $p$ ,  $v$ ,  $t$  are known. If a curve be used to represent a series of changes in the pressure and volume of a given gas, a similar curve can be constructed referred to  $t$  and  $\phi$  co-ordinates, representing varying values of  $t$  and  $\varphi$  corresponding to the different values of  $p$  and  $v$ , as shown by the curve.

The transforming equations present, however, some difficulty on account of the constant of integration  $C$ , which determines the position of the origin of co-ordinates. Apparently  $\phi$  should reduce to zero when  $t$ ,  $p$  or  $v$  is equal to zero. We then have

$$\varphi = 0 = \text{hyp. log.} 0 + C = -\infty + C \text{ and } C = \infty$$

By placing the origin at a distance  $C$  from the true origin at infinity, we can and do disregard the constant. Besides, all calculations deal with differences and variations of the function  $\phi$ , rather than with its absolute value.

Hence

$$\varphi = 0 \text{ when } t_v^{\gamma-1} = \frac{p v^\gamma}{R} = t^\gamma p^{1-\gamma} = 1$$

*Heat Absorbed during a Series of Changes.*—From equation. (5) we have

$$t d\varphi = dH \text{ and } H = \int t d\varphi \quad (9)$$

This can be integrated when the law of variation between  $t$  and  $\varphi$  is known, or when either  $t$  or  $\varphi$  is a constant.

Equation (9) can be represented by an area just as  $\int p \, d v$  is represented. Let us assume the abscissas to correspond to the values of  $\phi$  and the ordinates to represent values of  $t$  (Fig. 1).

In adiabatic expansion the value of  $H$ —the actual heat absorbed during expansion—reduces to zero, and hence

$$H = \int t \, d \varphi = 0 \text{ or } \varphi = \text{constant.}$$

In Fig. 1, the straight line  $A B$  represents adiabatic (isentropic) changes between limits of temperature corresponding to  $A$  and  $B$ ; the straight line  $C D$  represents isothermal changes between limits of  $\varphi$  corresponding to the points  $C$  and  $D$ ; while the line  $E F$  may represent any known series of changes between the limits of  $\varphi$  and  $t$  corresponding to the co-ordinates of the points  $E$  and  $F$ .

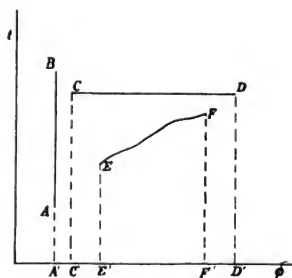


Fig. 1.

The areas  $A B A'$ ,  $C D C' D'$  and  $E F E' F'$  represent each the quantity of heat which must be supplied to produce the changes represented by the lines  $A B$ ,  $C D$  and  $E F$ , respectively, i e., values of

$$\int_{\varphi'}^{\varphi''} t \, d \varphi$$

If the series of changes take place in the opposite direction, from  $F$  to  $E$ , from an initial value of  $\varphi$  to a smaller final value,

then the area will be measured in the opposite direction and will be negative. It will then represent heat which must be abstracted from the changing gas.

Figs. 2 and 3 represent corresponding changes in  $p$  and  $v$  and  $t$  and  $\varphi$ ; they give all the particulars concerning the conditions of the gas.  $P$  ( $P'$ ) is supposed to be the initial condition, while  $P I$  ( $P' I'$ ),  $P A$  ( $P' A'$ ),  $P D$  ( $P' D'$ ), and  $P F$  ( $P' F'$ ) show respectively isothermal, adiabatic, isometric and isopies-tic changes. Line  $P C$  ( $P' C'$ ) shows that heat is given out, although the gas is expanding and doing work; while line  $P E$  ( $P' E'$ ) is absorbing mechanical energy during compression and at the same time requires a supply of heat energy.

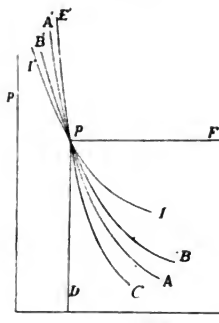


Fig. 2.

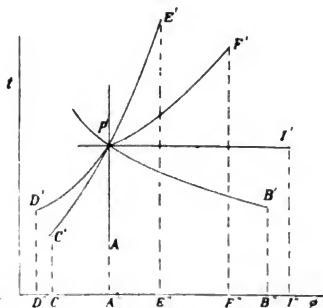


Fig. 3.

*Heat Required during Cycle.*—A cycle of operation may be represented by a closed figure (Fig. 4).

Draw two adiabatics  $\varphi'$  and  $\varphi''$  and two isothermals  $t''$  and  $t'$  tangent to the given area, thus circumscribing it, the points of tangency being the points  $A B C$  and  $D$ . Let the changes follow one another in the direction indicated by the arrow in the diagram. The area  $\varphi' A B C \varphi''$  will represent the quantity of heat which must be supplied during the changes from  $A$  through  $B$  to  $C$ . This quantity,

$$\int_{\varphi'}^{\varphi''} t d\varphi,$$



will be positive. In a similar manner the changes from  $C$  through  $D$  to  $A$  are accompanied by a production or evolution of sensible heat represented by the area  $\phi'' C D A \phi'$ . This area,

$$\int_{\phi''}^{\phi'} t d\phi,$$

will evidently be negative. The algebraic sum of these two areas gives the area enclosed by the irregular line  $A B C D$  and represents the total amount of heat which disappears as heat, *i. e.*, is absorbed during the cycle and appears as mechanical energy or work.

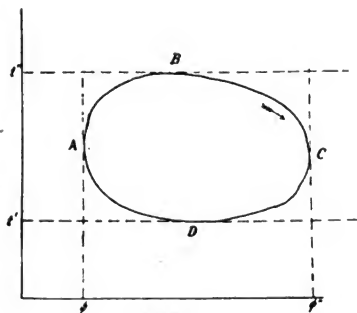


Fig. 4

If, therefore, we chose our units in the two diagrams properly, this area referred to  $t$  and  $\phi$  co-ordinates will be exactly equal to the area of the diagram of a cycle of changes referred to the ordinary co-ordinate axes  $v$  and  $p$ .

*Mechanical Energy.*—In order to get an area representing the mechanical energy developed during any changes, such as those represented by the line in Fig. 5, we proceed as follows:

$$\phi' A B C \phi'' = \int t d\phi = H = K_v \int d t + R \int t \frac{d v}{v}$$

See eq. (4).

where

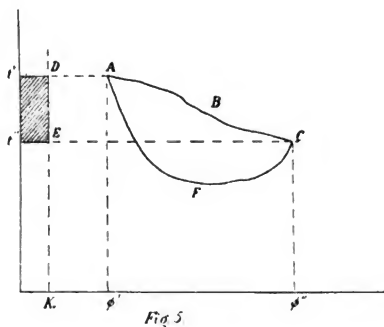
$$R \int t \frac{dv}{v} =$$

mechanical energy developed.

$$K_v \int dt = K_v (t'' - t')$$

where  $t'$  is the initial temperature at the point  $A'$ , and  $t''$  is the temperature at the point  $C$ , the end of the changes.

Draw the line  $K_v$ , distant from the axis of  $t$  by an amount equal to  $K_v$ ; then will the shaded area  $t' t'' D E$  represent  $K_v (t'' - t')$ .



Hence from equation (4)

$$\int t d\phi - K_v \int dt = R \int t \frac{dv}{v} = \text{work}$$

and area  $\phi' A B C \phi'' + \text{area } t' t'' D E = \text{Work}$ .

Here we assumed  $t'$  greater than  $t''$ , and hence the area  $t' t'' D E$  is negative, and the work performed is really the arithmetical sum of the two areas.

Passing back to  $A$  through any series of changes as along the line through  $F$ , the same area will represent  $K_v (t' - t'')$ , but will be positive since now the final temperature is higher than the initial.

Thus during a cycle represented by the successive changes along  $A B C$  and then back along  $C F A$ , the work done is

represented by the area enclosed,  $A B C F A$ , since the two equal areas  $E t'' t' D$  with opposite signs counteract each other and disappear in the result.

It is, therefore, evident that any area enclosed by lines representing a series of changes of values of  $\varphi$  and  $t$  is equal to the corresponding area enclosed by the lines representing varying values of  $p$  and  $v$  (Fig. 6).

Area  $\varphi A B C \varphi''$  of Fig. 5 is equal to the area  $\varphi' A B C \varphi''$  of Fig. 6, the curves  $\phi'$  and  $\phi''$  being extended to infinity; and hence the latter represents the quantity of heat absorbed during the changes along the line  $A B C$  (Theorem, p. 303. Rankine, Steam Engine, etc.).

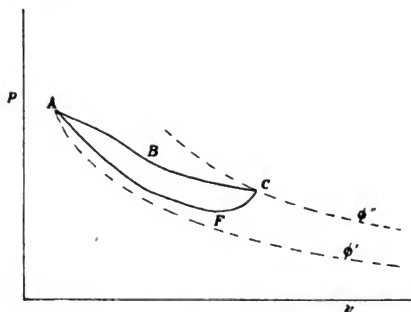


Fig. 6.

*The Second Law of Thermodynamics.*—The second law of thermodynamics can now also be represented in a simple manner (Rankine, § 244, p. 308). In Fig. 7,  $AB$  represents an isothermal expansion at temperature  $t$ ; and the area  $\varphi' A B \varphi''$  represents both the heat absorbed during this expansion as well as the mechanical work performed.

This area may be divided into equal parts by simply dividing  $t$  into equal parts and drawing the isothermals  $CD$ ,  $EF$ , etc.,  $ABCD = CDEF =$  etc. Hence every part of the temperature affects the work by the same amount.

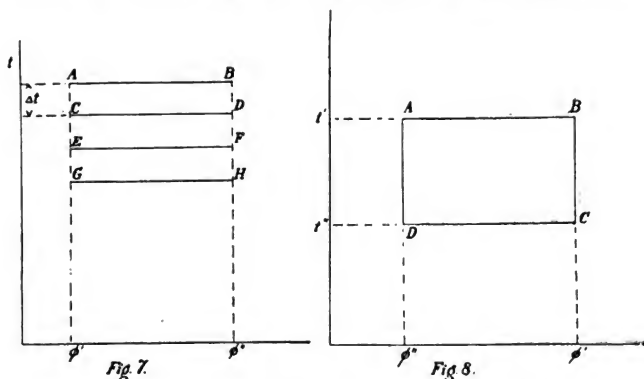
*Carnot's Cycle.*—Fig. 8 represents the diagram of the elementary engine (Carnot's cycle). The area  $(t' - t'') (\varphi' - \varphi'') = ABCD$  is evidently the work performed during the cycle,

while  $\varphi'' A B \varphi' = t' (\varphi' - \varphi'')$  represents in the same units the quantity of heat absorbed during and hence required by the cycle. The efficiency of this engine is, therefore,

$$\frac{(t' - t'') (\varphi' - \varphi'')}{t' (\varphi' - \varphi'')} = \frac{t' - t''}{t'}$$

*Maximum Efficiency.*—Fig. 9 represents the diagram of any engine, and the circumscribing rectangle  $A B C D$  represents the work done by an elementary heat engine acting between the same limits.

The efficiency of the former is the ratio: (Irreg. area,  $E F G H I$ , etc.)  $\div \varphi'' E F G \varphi'$ , while the efficiency of the



latter is the ratio:  $A B C D / \varphi'' A B \varphi'$ , where  $A B C D = E F G H + E F A + F B G + G C H + H D E$  and  $\varphi'' A B \varphi' = \varphi' E F G \varphi'' + E F A + F B G$ .

Subtracting from both the numerator and the denominator of the fraction  $A B C D / \varphi'' A B \varphi'$  the same quantity  $E F A + F B G$ , we get

$$\frac{E F G H + G C H + H D E}{\varphi'' E F G \varphi'}$$

which is less than the original ratio

$$\frac{A B C D}{\varphi'' A B \varphi'}$$

and hence

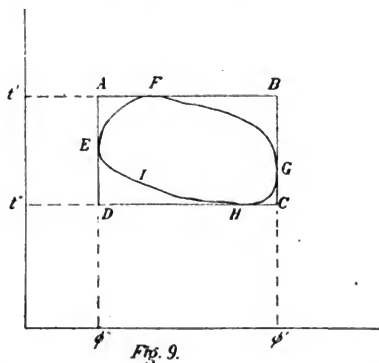
$$\frac{E F G H}{\varphi'' E F G \varphi'}$$

is still less than the same ratio

$$\frac{A B C D}{\varphi'' A B \varphi'}$$

(NOTE.—It is easily shown that if both numerator and denominator of a fraction whose value is less than unity be decreased by the same amount, the resulting fraction is reduced in value.)

We thus reach the conclusion given by Rankine, on pages 265, 266 and 267, that the highest possible efficiency between



given limits  $t'$  and  $t''$  is the ratio  $A B C D / \varphi'' A B \varphi' = (t' - t'') / t'$ , and corresponds to the efficiency of an elementary heat engine.

*Isodiabatic Lines—Regenerator.*—Fig. 10 represents isodiabatic lines, which appear simply as lines parallel to each other, or rather as lines equidistant at all points, the distances being measured parallel to the axis of  $\varphi$ .

Points  $A$  and  $D$  have equal ordinates (temperature  $t'$ ); similarly  $B$  and  $E$  correspond to the temperature  $t''$ ;  $A B$  and  $D E$  are parallel. Therefore, the areas  $\varphi' A B \varphi''$  and  $\varphi''' D E \varphi''$  are equal, and the same quantity of heat is absorbed in chang-

ing from  $A$  to  $B$  as from  $D$  to  $E$ , *i. e.*, between the same temperatures  $t'$  and  $t''$ .

We can readily show that isometric as well as isopiestic lines are isodiabatic.

From equations (6) and (8), we have

$$\varphi = \text{hyp. log. } t^{Kv} + R \text{ hyp. log. } v + C$$

and

$$\varphi = \text{hyp. log. } t^{Kp} + R \text{ hyp. log. } R / p + C$$

If  $v$  is constant, we get the logarithmic curve

$$\varphi_v' = \text{hyp. log. } t^{Kv} + \text{constant } C'$$

depending on the value of  $v$  ( $= v'$ ).

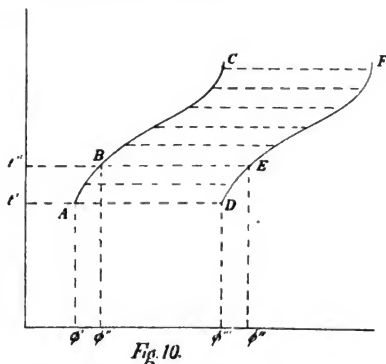


Fig. 10.

For any other value  $v$  ( $= v''$ ), we get

$$\varphi_v'' = \text{hyp. log. } t^{Kv} + C''$$

depending on  $v''$ .

At equal temperatures,

$$\varphi_v' - \varphi_v'' = C' - C'' = \text{constant.}$$

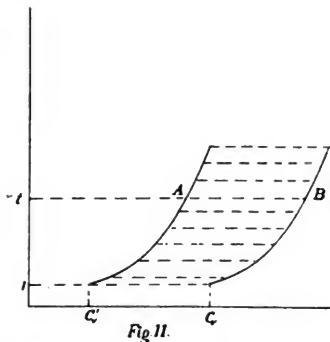
See distance  $AB$ , Fig. 11.

Similar reasoning applies to lines of equal pressure, isopiestic lines.

The area enclosed by two isothermals and two isodiabatics, whose abscissas differ by the constant  $\varphi_1 - \varphi_2$ , is equal to the

rectangle  $(t' - t'') (\varphi_1 - \varphi_2)$ . This is evident since the area is made up of infinitesimal areas  $(\varphi_1 - \varphi_2) dt$ , which, when added, give the total area  $(\varphi_1 - \varphi_2) \int dt = (\varphi_1 - \varphi_2) (t' - t'')$ .

Let Fig. 12 represent such an area  $A B C D$ . Then the efficiency of such a cycle is represented by the ratio  $A B C D / \varphi' A B C \varphi''$ , or its equal  $A' B C D' / \varphi' A B C \varphi''$ , provided all the heat represented by the area  $\varphi' A D C \varphi''$  is lost as available heat. If, however, the heat given out during the changes from  $C$  to  $D$  be taken up (absorbed) by a "regenerator" and then returned or re-supplied to the medium while passing from  $A$  to  $B$ , then the area  $\varphi''' D C \varphi''$  represents that heat. To find the efficiency in that case we must subtract this



area from the denominator of the above ratio. Since the lines  $A B$  and  $D C$  are isodiabatic, the area  $\varphi''' D C \varphi'' = \varphi' A B \varphi'''$ , and hence the efficiency will be

$$\frac{A' B C D'}{\varphi' A B C \varphi'' - \varphi''' D C \varphi''} = \frac{A' B C D'}{\varphi' A B C \varphi'' - \varphi' A B \varphi'''}$$

$$\frac{A' B C D'}{\varphi''' B C \varphi''} = \frac{t' - t''}{t'}$$

This value  $(t' - t'') / t'$  we recall as the maximum possible between the given limits of temperature (vid. Rankine, § 273. etc.).

We notice that, theoretically, the successive portions of

the regenerator must assume the decreasing temperatures corresponding to the successive points of the line  $CD$ . During the "regeneration" the temperature of the medium will change in the reverse order, and as the gas passes through the regenerator in the opposite direction, it will encounter temperatures corresponding to its own. Hence a transfer of heat is possible, if the "heat-capacity" (specific heat and mass) of the regenerator is high, and if its different portions are sufficiently "insulated" from each other.

If the lines  $AB$  and  $CD$  are not parallel, changes between equal temperatures will require different quantities of heat  $\int t d\varphi$ , and hence a complete transfer will not be possible.

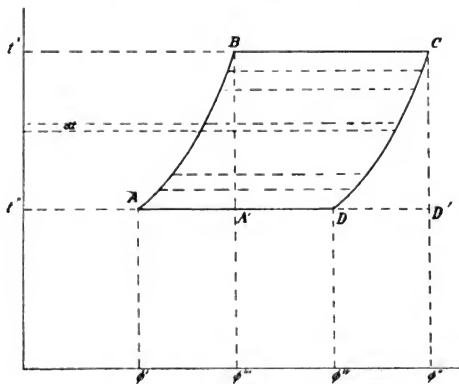


Fig. 12.

*Applications.*—The advantage of the  $t\varphi$  diagram is the fact that it represents by finite areas both the work performed and the heat supplied during a cycle of operations, such as a revolution of the hot-air engine.

The discussion may be made general, but somewhat more difficult, by insisting on the value  $dp/dt$  instead of  $p/t$  in the original equation, and introducing molecular internal action, as in the case of liquids and imperfect gases.

In that case we can still suppose the variation of  $\varphi$  to be known, and we can still construct the diagram of a cycle.





given temperature and pressure. The adiabatic  $CD$  gives the most efficient reduction of temperature, down to that of the feed water,  $t''$ .  $DA$  shows the isothermal recondensation of the steam. Here also the rectangle  $AD\phi'''\phi'$  includes simultaneously the energy of compression and that of reintegration into water.

The efficiency of the steam engine is thus seen to correspond very closely to that of Carnot's cycle. Unfortunately, the line  $CD$  is not attainable in practice, as the water in the expanding steam causes dissipation of energy by facilitating the radiation losses. The function  $\varphi$  is, therefore, diminished, and a curve similar to  $CE$  ensues, yielding a much smaller enclosed area, and hence lower efficiency. The point  $C$  is the cut-off, and the point  $F$  may be used to represent the end of the stroke, unless the expansion is continued till the lower temperature  $t''$  is reached.  $FG$  may then show an isopiestic or other fall in the temperature, as met in reality.

$CH$  represents the logarithmic curve, showing superheating;  $\varphi = K_v \text{ hyp. log. } t$ , where  $K_v$  is the specific heat of the steam-gas.  $HI$  then gives the adiabatic fall in temperature of the steam-gas.  $\varphi'''CH\varphi''$  is the additional heat required, and  $CHIE$ , the additional work performed. The economy of superheating can be shown to depend on the fact that the fall in temperature can be more closely along the adiabatic line  $HI$ , than  $CE$  can be made to approximate the adiabatic  $CD$ .

Lastly, the curve  $CI$  corresponds to saturated steam at the various temperatures. It is seen that a jacket is required to supply the additional heat measured by the area  $\varphi'''CI\varphi''$ .

In a similar manner other topics, presenting greater or less difficulty, can be illustrated and simplified. Thus comparisons between different types of engines and engines using different fluids can be made diagrammatically, because the figures show both the work performed and the heat energy supplied, and hence also the efficiency. On the other hand, the  $p\ v$  diagram gives only the mechanical energy developed.

## CHEMICAL SECTION.

*Stated Meeting, of Tuesday, January 13, 1898.*

DR. LEE K. FRANKEL, President, in the chair.

### THE DETECTION OF SALICYLIC ACID IN FOODS.

(PRELIMINARY NOTE.)

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BY F. A. GENTH, JR.

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In the examination of foods for salicylic acid, the so-called distillation method, suggested by G. Krause and fully described by Mr. McElroy, is the one most frequently used.

The method is as follows: The mass is pulped with phosphoric acid in a mortar, water added if necessary, and after some time strained through a cloth. About 50 to 75 cubic centimeters of the liquid is then subjected to distillation and successive portions of 5 cubic centimeters each of the distillate collected and tested with ferric chloride. If salicylic acid has been used as a preservative, it will be distilled with the water vapor, and give a violet coloration when ferric chloride is added. In the first portions of the distillate no reactions may be obtained, and in cases where only very small amounts of salicylic acid are present in the article under examination, the reaction in the last portion of the distillate would not be very marked. The methyl ester reaction, which is likewise recommended as a test for salicylic acid, cannot always be obtained when the amount present is small.

No other substances have been known to yield distillates giving similar colorations, or any reactions interfering with that for salicylic acid under the above circumstances.

The writer has recently had occasion to examine a series of preserves, such as jellies, jams, catsup, etc., for preservatives. Among the samples submitted were a number obtained through the courtesy of Food Inspector H. J. Hackett, and were known to be free from salicylic acid or other preservatives. In the examination of these latter samples according to the above described method, a color reaction similar to that

given by salicylic acid was found in all cases. When tested with ferric chloride, the first portions of the distillate showed little, if any coloration, and only as the distillation continued did it become more marked. In many cases the distillation process was not continued to within the last 10 cubic centimeters, but was stopped with over 25 cubic centimeters still remaining in the flask. The coloration in dilute solutions was violet, of about the shade and color of similar ferric salicylate solutions; in more concentrated solutions the color was much redder in the case of the distillate from the pure food, and was found to effectually hide the presence of small amounts of salicylic acid, when added.

The nature of the distillates and the examination of food-stuffs for salicylic acid will be further investigated.

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#### CORRESPONDENCE.

#### SCIENCE AND THE SOCIETY OF FRIENDS.

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*The Editor Journal Franklin Institute:*

SIR:—In his recent speech at the Bishop McVickar banquet, Mr. Joseph Wharton dwelt on a striking fact, known to the great majority of our citizens, but rarely emphasized. There are few Pennsylvanians who have not observed how frequently the names of Friends appear in the management of our railroad, coal and iron interests; how prominently the influence of Friends has appeared in the workings of the Franklin Institute; how the Friends have quietly and persistently worked for the advancement of science. Mr. Wharton forcibly referred to the debt of chemistry to John Dalton and the obligations of electricity to Thomas Young. He might have added that, when George Stephenson was looked on as a crack-brained empiric, a wealthy Friend advanced the money needed to help the infant locomotive on its way. The influence of the Friends as scientific pioneers is, perhaps, as decided as the influence of the Anglican Church on ecclesiastical music, or that of the Scotch Presbyterians on studies of a

metaphysical character. It is one of the facts in the history of industrial science which no student can fail to observe.

The reason of this scientific aptitude is seldom mentioned; but an adequate cause reveals itself to the investigator. Born in a rough, fighting age, the Society of Friends found the social life of England, indeed of the whole world, leavened with the warlike spirit. The famous Friend for whom this Commonwealth was named was the son of an admiral, and to that fact owed a large share of the court favor which he enjoyed. During the fierce wars with the Dutch in Charles II's time, it was almost necessary for a man who wished to figure in society to make at least one cruise against the enemy. The younger sons of the nobility and gentry sought eagerly for commissions in the army or navy. A drunken, brawling soldier or sailor was more highly esteemed by many, perhaps by a majority of the community, than the most exemplary baker or weaver. It was possible for a runaway apprentice or a friendless orphan to rise to distinction if he enlisted in the ranks or before the mast. Narborough and Shovel rose from cabin boys to admirals. From forecandle to quarter deck was no unusual change. Cut off from war, the energies of the Friends turned to farming, iron mining and various industries which gave opportunity for the talents and application which might have won promotion in fleet or army.

Poor boys, with no relish for martial pursuits, with studious habits and devotional inclinations, often looked to the Church. England's annals tell of many a bright lad, whose craving for knowledge pleased the village parson and the country squire. Such boys were helped in their studies, scholarships made their way less rugged, and, finally, the position of servitor at one of the universities would be held out to them. It required patience and self-denial, as well as industry, to pass through the numerous ordeals of a poor scholar, but it could be done, and George Whitefield and a host of others did it. The son of a mechanic or farmer might hope for a country vicarage or a headmastership, he might become tutor in a nobleman's family or end his days as a fellow in the college where he wrestled with Aristotle's logic or translated St. Augustine's

Confessions. From the prizes of the Church the Friend could receive nothing. He rejected its entire system of worship and government. The existence of a settled, paid ministry was to him a stumbling block, and his scruples, if they excluded him from cockades and garters, also barred the way to lawn sleeves and doctor's hoods.

Youths for whom neither the camp nor the chancel possessed any fascination saw a road to advancement in the legal profession. Blackstone shows his apprehension lest the bar would be largely controlled by persons who had not received a classical education. Industrious boys made themselves useful to attorneys, and gradually built up lucrative practices. Steady lads, who never won the fame of Coke, yet rivalled him in the severity of their labors, and reached a gratifying degree of success. The Friend, who would not fight, and who would not read the Book of Common Prayer, objected to an oath, and this scruple kept him out of the courts and bade him entertain no hope whatever of public office. A host of public positions tempted other men, but the Friend, who refused to swear before any tribunal, knew that law and politics were not for him. Generations passed before he was allowed to give his simple affirmation in testimony of a fact. His creed banished him from the normal channels of ambition, and from the favorite amusements of society. Bear baiting, cock fighting, the prize ring and many of the sports in which the Merry Monarch's courtiers delighted would have disgusted the followers of Fox and Barclay. It was almost a necessity for the Friends to hew out new occupations and find some work that might test the capacities of their young men. What they have done in botany and metallurgy, in mining and agriculture, in chemistry and electricity requires a volume rather than a newspaper article. The reason of their activity in scientific pursuits is, we think, to be found in the facts to which we have called attention.

ROLAND RINGWALT.

## NOTES AND COMMENTS.

## THE BEET-SUGAR INDUSTRY.

It is gratifying to be able to note the steady growth of the beet sugar manufacture, which, after numerous fruitless efforts in the past, now appears to be not only firmly founded, but to be assured of a rapid growth. At the close of last year there were in operation in the United States nine factories, as follows: Rome, N. Y., daily capacity, 200 tons of beets; Lehi, Utah, 350 tons; Los Alamitos, Cal., 350 tons; Eddy, N. M., 200 tons; Chino, Cal., 700 tons; Norfolk, Neb., 350 tons; Grand Island, Neb., 350 tons; Alvarado, Cal., 500 tons, and Watsonville, Cal., 1,000 tons. The Spreckels interests are engaged in building, at Salinas, Cal., a factory having 3,000 tons daily capacity, and a dozen other new factories in California, Wisconsin, Kentucky, Iowa and Indiana are projected. This industry, perhaps more than any other, except the strictly chemical industries, is dependent upon skilled scientific superintendence for its successful development, and the circumstance that American capitalists are still largely dependent on foreigners for the machinery and skilled superintendence demanded in the business has proved, thus far, a serious obstruction. These difficulties, however, are being gradually overcome, and it is almost safe to predict that a few years more of systematic effort will suffice to place the beet-sugar industry in a position independent of foreign assistance for its development.

W.

## PROGRESS IN NAVAL ARCHITECTURE.

The past year witnessed unusual advances in the construction of fast steamships for the Atlantic passenger service. In this field the honors have been carried off by the German shipbuilders, as the record-breaking performance of the magnificent *Kaiser Wilhelm der Grosse*, lately put in service, bears witness.

This superb specimen of naval architecture is being duplicated in a sister ship, the *Kaiser Friedrich*, which has just been launched, and will take her place in the fleet of the North German Lloyd line in the course of a few months. The tendency to increase the tonnage of freight steamers is conspicuously shown by the recent addition to the fleet of the Hamburg-American line of the *Pennsylvania*—the first of several similar ships—with a length of over 600 feet, and a load-line displacement of more than 23,000 tons. Noteworthy in the field of shipbuilding, also, is the circumstance that the "White Star" line has now in course of construction for its Atlantic passenger service, a fast steamer, which will exceed not only in length but in a number of other details the hitherto unequalled *Great Eastern*.

Among the novelties in marine construction which came into prominence last year, should be numbered the "roller" vessels of Bazin, in France, and Knopf, in Canada. The fundamental idea involved in the designs of these vessels is, that a ship will advance more readily by rolling over the surface of the water than by forcing her way through it. The trials of these marine novelties failed to justify the views of their inventors.

## ELECTRIC RAILWAYS OF EUROPE.

*L'Industrie Electrique* has just published a complete list with details of the electric railways now operating on the Continent of Europe and Great Britain. The summary, which we print herewith, shows that Germany is far ahead of any other European country in both the number of electric railways and in the length of mileage, etc. It is interesting to note, also, that Germany has four roads using storage batteries, and France five such roads. Switzerland also makes a very good comparative showing. Considering the number and density of the population of Europe, that continent ought to be a veritable paradise for manufacturers of electric railway apparatus:

	Total Length of Lines in Kms.	Total Power in K. W.	Number of Mo- tor Cars.	Lines with Aerial Conductors.	Lines with Un- dergr. Cond.	Lines with Cen- tral Rail.	Lines with Accu- mulators.	Total No. of Lines.
Germany . . . . .	642.69	18,963	1,631	45	2	—	4	51
England . . . . .	109.42	4,670	168	10	1	6	1	18
Austria-Hungary . . . . .	83.89	2,589	194	7	2	—	1	10
Belgium . . . . .	34.90	1,220	73	4	1	—	—	5
Bosnia . . . . .	5.60	75	6	1	—	—	—	1
Spain . . . . .	47.00	600	40	3	—	—	—	3
France . . . . .	279.36	8,756	432	19	1	1	5	26
Holland . . . . .	3.20	320	14	—	—	—	1	1
Ireland . . . . .	18.00	486	32	1	—	1	—	2
Italy . . . . .	115.67	5,970	289	9	—	—	—	9
Sweden-Norway . . . . .	7.50	225	15	1	—	—	—	1
Portugal . . . . .	2.80	110	3	1	—	—	—	1
Roumania . . . . .	5.50	140	15	1	—	—	—	1
Russia . . . . .	14.75	870	48	2	1	—	—	3
Servia . . . . .	10.00	200	11	1	—	—	—	1
Switzerland . . . . .	78.75	2,622	129	17	—	—	—	17
Totals . . . . .	1,459.03	47,506	3,100	12	8	8	12	150

## RAILWAY CONSTRUCTION IN 1897.

The *Railway Age* of Chicago makes the following statement regarding new railway lines built in the United States in 1897:

While the year 1897 has shown larger railway earnings and better business conditions than its immediate predecessors, the marked improvement in the financial outlook did not begin early enough in the year for the completion of many new railway undertakings, and so it now appears that, although



much construction work is under way, the mileage of track actually laid is but little greater than that for the preceding year.

The lowest point in twenty years in respect to railway building was reached in 1895, when only 1,803 miles of track were added, and 1897 has done a little better, the total now reported to us being 1,864 miles. California stands first with 210 miles laid on different roads, and no track was laid in New Hampshire, Rhode Island, Connecticut, Maryland, Kansas, Nebraska, New Mexico, Indian Territory, Arizona, Wyoming and Nevada, and five others barely escaped from this category. At the commencement of 1898 the United States will have 184,464 miles of completed railway.

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#### ELECTRICAL PROGRESS.

On the threshold of the new year Mr. Tesla announces certain important advances in vacuum-tube lighting. He appears to have succeeded in increasing the intensity of the light obtainable from these tubes of highly rarefied gas, many hundred and even thousand times, and believes that he is still far from having attained the limit in the amount of light producible by this method. With this increase in intensity of the light, he claims to have effected, also, a notable increase in economic efficiency. While the details of the system have not yet been disclosed, the improvements realized are said to have been achieved by the gradual perfection of the means of producing, economically, harmonical electrical vibrations of extreme rapidity. In a communication on the subject which has just appeared in the *Electrical Review*, a photograph is shown, made on an exposure of two seconds, with the light of one of those tubes having an intensity of 1,000 candles. This picture is remarkable for the strong contrast of the lights and shadows, suggesting, in this respect, the well-known "flash light" photograph. The bearing of these important advances on the subject of lighting in general is obvious.

The experiments of Lieutenant Squier and Dr. Crehore, who have made use of the alternating current and specially designed receiving and transmitting devices to utilize high speeds in telegraphing, have attracted much attention. The capabilities of their method have been put to test by Professor Preece, the Director of the Telegraphs of the British Government, and the results, which will shortly appear in the *Journal*, are highly encouraging.

The name of Marconi, an Italian experimenter, also figured conspicuously in the electrical journals in connection with the problem of telegraphing without the use of wires. It has been stated that by the method employed by this investigator he has succeeded in transmitting intelligence over a distance of eight miles without the use of wires. For this purpose Marconi utilizes the Herzian vibrations. His system has also been made the subject of special investigation by the British telegraphic service.

No radical changes in telephony were introduced last year, but numerous improvements affecting the efficiency and economy of the service have been introduced. There was also a considerable extension of the long-distance system.

The rapid growth of independent telephone lines during the past year is the most noteworthy incident in connection with the subject. The innovation has been confined principally to the smaller cities of the country, which have heretofore been without the advantages of the telephone, but it is rapidly

extending to the larger cities. The *Western Electrician* mentions among the larger municipalities that have been supplied with an independent telephone service, Detroit, Fort Wayne, Mobile, Sacramento, Cleveland, Baltimore, Newark, Richmond, Norfolk, and others. A large amount of capital is already invested in independent telephony; about 1,100 exchanges are in operation and in course of construction, and 20,000 miles of toll lines owned by the independent companies are completed, while many thousand miles of line are in process of construction.

The substitution of electric traction for steam traction on suburban lines has made steady progress during the year just passed, and, in connection with this phase of the subject, the experiments made by the New York, New Haven and Hartford Railroad on one of its branches, with the third-rail system, has been widely commented on, and generally with favor, as portending the gradual adoption of election traction for certain forms of heavy suburban traffic. The announcement made within the past few days that the elevated railways of New York are to be equipped with this system as soon as the change can be made from steam to electricity, is another evidence of the tendency in this direction.

In electric power transmission there has been a decided advance during the past year, not only in the United States, but also in European countries. The Niagara plant has nearly doubled its former output, and the extension of its service to Buffalo is worthy of special mention.

The great extension of the introduction of the electric motor for miscellaneous uses, especially for the direct operation of machinery, is one of the most significant facts bearing on the future of this type of prime mover. For driving elevators, printing-presses, blowing and exhaust apparatus, machine tools, etc., and especially for transmitting power where the work is intermittent in character, the economy and convenience of the electric motor have gained for it general recognition.

W.

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#### METAL AND MINERAL PRODUCTION OF THE UNITED STATES IN 1897.

The *Engineering and Mining Journal* places the total value of the mineral and metal production of the United States at over \$762,000,000. The values given in the *Journal's* statistical tables are of the products in their crudest forms—coal at the mine, coke from the ovens, pig iron from the furnace, etc. It is noted that the value of the annual product of the United States in 1897 exceeds that of any previous year; also, it greatly exceeds that of any other country, and nearly equals that of all Europe.

The *Journal* says: "The production of 1897 emphasizes not only the great total value, but also the immense variety of the mineral production of the United States. Not only is this country the largest producer of iron and steel, of copper, of lead, of silver and of gold, but almost every mineral and metal known to commerce is found within our borders, and is mined or prepared in some quantity."

We give from the same authority a few only of the more important items:

The production of gold in the United States in 1897 was 2,685,000 fine ounces, valued at \$55,498,950, an increase in value of about two and a quarter

million dollars over 1896. The State of Colorado, it is worth noting, largely increased its gold production and now has the largest output of any State in the Union. The production of silver amounted to 56,117,000 ounces, of the value of \$33,557,966, a decrease of about two million ounces in quantity, and of about five and a half million dollars in value, as compared with 1896.

The production of copper in 1897 reached 475,338,340 pounds, an increase of nearly eight million pounds over 1896.

The output of lead was 194,532 short tons, valued at about \$14,000,000, a substantial increase over the previous year.

The aluminum industry received a decided impetus last year, the production rising from 1,300,000 pounds, valued at \$520,000, in 1896, to 4,000,000 pounds, valued at \$1,542,240, in 1897.

The output of coal was, in round numbers, 194,500,000 tons, of which 49,500,000 tons were anthracite and 145,000,000 bituminous. The aggregate value of this production was \$205,500,000. Large as this output is, it is still below that of Great Britain.

Of coke we produced 11,774,000 short tons, of the value, in round numbers, of \$21,500,000.

Of iron ore our production was 17,846,000 tons, of which 12,550,000 tons was from the Lake Superior region.

The production of pig iron was 9,491,796 tons, a large increase over 1896, and the largest output ever before reported. The figures for the production of steel are not yet available, but they will probably reach 6,500,000 tons. Noteworthy is the circumstance that the production of open-hearth steel is advancing rapidly and at present forms about 25 per cent. of our total product. All of this form of steel is used in structural work of various kinds. Other notable items in connection with the iron and steel industries are the successful inauguration of the basic steel process in the Birmingham district in Alabama; the adoption of the improved Hoffman coke ovens by one of the largest Pennsylvania steel works, and the tendency on the part of the great iron and steel works towards the enlargement of the size and capacity of blast furnaces, and the reduction in all directions of costs of production by the adoption of improved methods of handling material. The direct consequence of these circumstances and the concentration of the business of mining and transporting ores, is seen in the fact more generally known that the various finished products of iron and steel are now made in the United States more cheaply than in any other country. The development of a considerable and and constantly growing export trade in these products is one of the most creditable and gratifying symptoms of our present industrial situation.

A decided increase in the domestic production of tin and terne plates in 1897 is a gratifying fact to notice. Special Agent Ayer's report shows the production during the fiscal year ended June 30, 1897, was 446,982,063 pounds, of which about 88 per cent. was of the class weighing lighter than 63 pounds per 100 square feet.

This is an increase in production of nearly 140,000,000 pounds, or over 45 per cent., as compared with 1896. The total importation during the year was 244,407,601 pounds, and the exportation for the same period 139,946,130 pounds, making the net imports 105,161,471 pounds. The production of the United States, therefore, was more than four-fifths of the entire consumption.

The annual capacity of mills completed and in process of construction, June 30, 1897, is said to be about 650,000,000 pounds. The production of black plates aggregated 436,438,035 pounds, an increase for the year of 102,423,237 pounds.

The permanent establishment of this important industry is now an accomplished fact, and it is even asserted with confidence that within a very few years American manufacturers will have succeeded not only in fully supplying our domestic requirements, but also to compete in foreign markets for the disposal of a considerable surplus. W.

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## BOOK NOTICES.

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*The Entropy-Temperature Analysis of Steam Engine Efficiencies, with a Blank Diagram Arranged for Easy Application to any Concrete Case.* By Sidney A. Reeve, M.E., Adjunct Professor of Steam Engineering at the Worcester Polytechnic Institute, New York. Progressive Age Publishing Company. 1897. Twenty pages.

We have long been using hydraulic analogies for forming conceptions of electrical phenomena. The first half of Mr. Reeve's book gives us a welcome hydraulic analogy for the cycle of a heat engine. He represents the working substance of the engine as a water-wheel carrying buckets full of entropy from a high level to a low one.

In the second part of his book he gives a very elegant graphical solution of the problem of changing an ordinary pressure-volume indicator-card into a temperature-entropy diagram. The various losses in the cylinder are then determined from this diagram.

Temperature-entropy diagrams have been attracting much attention lately, but Mr. Reeve's method involves less labor than any other that we have seen. It may be performed by one unfamiliar with the calculus. Other articles on this same subject have appeared during the last few years in London *Engineering*, for December 6 and 20, 1895, and for January 3 and August 14, 1896. The question was treated at the spring meeting of the American Society of Mechanical Engineers, in the discussion of the paper on "Adiabatics. A more extensive treatment, by Prof. M. J. Bonevin, of the University of Ghent, may be found in the *Revue de Mécanique*, January to June, 1897.

E. T. C.

## Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, February 16, 1898.*]

HALL OF THE FRANKLIN INSTITUTE,  
PHILADELPHIA, February 16, 1898.

MR HENRY R. HEYL, in the Chair.

Present, 78 members and visitors.

Additions to membership since last report, 14.

The resignations of Messrs. George H. Frazier and Samuel M. Vauclain from the Board of Managers were filled by the election of Messrs. Stephen Greene and Henry Howson.

Prof. L. F. Rondinella, Chairman of the Committee on Science and the Arts, gave a brief *résumé* of the Committee's work. He called attention to the fact that the condition of the several medal trust funds controlled by the Institute would warrant the grant of a considerably greater number of such awards than the Institute had been giving during the past few years. It would be a great help to this end if the members of the Institute would recommend to the Committee on Science and the Arts subjects for the investigation in the form of discoveries, inventions, etc., of sufficient merit to be deserving of such recognition. The chairman earnestly requested the members to assist the Committee by transmitting suggestions of this nature through the Secretary.

The paper of the evening was presented by Dr. Leonard Waldo, of Bridgeport, Conn., on "The Evolution and Present Manufacture of the American Bicycle." The paper was profusely illustrated by means of models of machines of various types dating from the early part of the present century down to the most improved types of the present time, and by numerous lantern slides, exhibiting the historic development of the bicycle and the elaborate and refined processes of manufacture employed in the representative American factory devoted to this industry.

At the close of the paper, the thanks of the meeting were voted to Dr. Waldo for his interesting and extremely valuable communication, which was referred for publication in the *Journal*, and the subject was referred to the Committee on Science and the Arts for investigation and report.

Adjourned.

WM. H. WAHL, *Secretary*.

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### COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held February 2, 1898.*]

MR. JAMES CHRISTIE in the chair.

Prof. L. F. Rondinella was elected Chairman of the Committee for the year 1898, and assumed the chair. The retiring chairman received a vote of thanks for his services.

Reports on the following subjects were considered :

*Franklin Institute Grand Medal.*—Further discussed and held under advisement.

*Wave Motors.*—Henry Lotzgesell, Philadelphia. Referred back to sub-committee.

The following were adopted:

*Compound Locomotive Engine.*—Clifton L. Reeves, Trenton, N. J.

ABSTRACT.—This invention is the subject of U. S. Letters-patent No. 585,331, June 29, 1897. It describes a 4-cylinder engine, two of which are inside and two outside the frame. In the one described the high-pressure cylinders are outside. The cranks are set opposite each other for each high- and low-pressure cylinder. The engine is supplied with the regulation balance valves, vacuum valves, live-steam valves, etc., all of which are well known in locomotive practice. The report concedes neither substantial novelty nor utility to the invention. [*Sub-Committee.*—Henry F. Colvin, chairman; Wilfred Lewis, Wm. Penn Evans.]

*Steel-lined Aluminum Culinary Ware.*—Romaine C. Cole, New York.

ABSTRACT.—This invention (see U. S. Letters-patent No. 513,762, January 30, 1897) describes a culinary vessel consisting of two metals, sheet steel and aluminum, drawn or stamped one within the other, the aluminum forming the inside and the steel the outside of the vessel. The advantages claimed by the inventor are, substantially, that to enable a vessel to cook quickly and to prevent scorching or burning of the food, the walls of the vessel should be of two or more layers, the outer one having a lower specific heat and lower thermal conductivity. Hence his proposal to form such vessels of the two metals above named in the manner above described.

The report of the Committee is unfavorable to the invention for the following reasons:

(1) Want of novelty; the stamping or drawing of one metal within another for substantially similar purposes being fully disclosed in U. S. Patent No. 60,770, January 1, 1867, to Phillip P. Meyer. (2) The claim to advantage on the score of using metals of different specific heats is denied, and that of the beneficial effect in preventing scorching or burning of food, it is affirmed, can be realized equally as well with vessels made from a single layer of aluminum. This advantage, admitting that it exists, does not depend, therefore, on the vessel being made of several layers. (3) The report finds the vessels mechanically defective, in that there does not exist in the samples submitted for examination the "intimate contact" claimed as a feature of the invention; neither did they exhibit the needful water-tight connection of the metals at the rim. "Both air and water, therefore, enter between the two layers forming the vessel, and when the latter is heated the bottom is deformed by the gases, tending to the destruction of the vessel." (4) There appears to be no advantages in these vessels over those of plain sheet aluminum on the score of cost. For these reasons the report is not favorable to the inventor's claim to novelty and utility. [*Sub-Committee.*—Charles James, Chairman; Geo. C. Reese, Joseph Richards, Oberlin Smith.]

SECTIONS.

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CHEMICAL SECTION.—*Stated Meeting* held Tuesday, February 15th, Dr. Lee K. Frankel in the chair.

Mr. Edward H. Earnshaw, Chemist to the United Gas Improvement Company, presented a paper on "The Chemical Composition and Analysis of Water Gas." The paper was freely discussed, and was reported for publication.

ELECTRICAL SECTION.—*Stated Meeting* held Wednesday, February 23d, Mr. Walter E. Harrington in the chair.

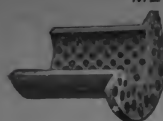
Mr. Herbert Laws Webb, of New York, presented a paper on "The Telephone Exchange," illustrated with numerous lantern slides. Referred for publication.

MINING AND METALLURGICAL SECTION.—*Stated Meeting* held Wednesday, February 9th, Mr. A. E. Outerbridge, Jr., in the chair. Mr. Paul Kreuzpointner, Testing Department, Pennsylvania Railroad, Altoona, Pa., read a paper entitled "The Practical Aspect of Present Methods of Testing Iron and Steel," illustrated with the aid of lantern slides and specimen test-pieces. Discussed and referred for publication.

*Special Meeting* of Thursday, February 24th. This was a joint meeting of the Section, and the Numismatic and Antiquarian Society of Philadelphia, Mr. A. E. Outerbridge, Jr., in the chair.

Captain E. L. Zalinski, U. S. A., presented a communication on "Japanese Swords." The subject was illustrated by the exhibition of a number of these weapons, among them several of very ancient date. The paper elicited considerable discussion, and was referred for publication.

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# THE JOURNAL OF THE FRANKLIN INSTITUTE

DEVOTED TO

—\* Science and the Mechanic Arts. \*—

EDITED BY

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SELLERS, E.D., Committee on Publications:

with the Assistance of

DR. WM. H. WAHL, Secretary of the Institute.

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## Mining and Metallurgical Section.

[*Stated Meeting, December 8, 1897.*]

### FATIGUE OF METAL IN WROUGHT IRON AND STEEL FORGINGS.

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BY MR. H. F. J. PORTER,

The Bethlehem Iron Company, South Bethlehem, Pa.

My connection with one of the large forges of the country has brought me for several years in contact with persons who use forgings of both iron and steel in their respective lines of business, and in conversation with them I have frequently been surprised at the misconception that many of them have regarding the comparative properties of these metals and especially their ability to resist repeated stresses.

They tell me, for instance, that they prefer wrought iron to steel for the connecting-rods and crank-pins of their engines, because steel, having no fiber, is brittle and snaps suddenly, while wrought iron, being fibrous, does not. They say that

both iron and steel crystallize from shock, but that wrought iron, being tougher, will outlast steel in such service as is performed by piston-rods of steam-hammers. They say that low carbon steel is softer than high carbon steel, and is, therefore, less brittle and not so apt to break in the forged parts of their machines.

Most of these persons know better, but have not given the subject sufficient thought, or they would perceive that their statements are not consistent.

They know that steel cannot at the same time be stronger than iron, and yet be more brittle.

There is not one of them who would advocate the use of the old "cut nail," which was made of iron in place of the "wire nail," which is made of steel. They all know, if they only call it to their minds, that all metals are crystalline, iron and steel among them, and those who have looked into the matter carefully, know that the fiber in wrought iron is due entirely to the slag which has been incorporated in it in the process of manufacture. Many of us have seen the laboratory experiment of passing chlorine gas through a glass tube containing a piece of wrought iron. We remember how the iron was dissolved out, leaving a skeleton of slag of the same shape as the piece of iron. Here and there in the interior of the skeleton could be seen accretions of slag which, imbedded in the original piece of iron, would have weakened it appreciably. Instead, therefore, of being an element of strength in wrought iron, the fiber, which is looked upon as adding strength, is evidence of an impurity which is a source of weakness. And yet this fibrous appearance is not a necessary characteristic of good wrought iron. Any blacksmith will break a bar of iron in such a manner as to cause either a fibrous or a crystalline fracture. Then, again, wrought iron may be so poorly manipulated in the puddling process that, if worked at too high a heat, a portion can become actually melted into steel, or, if at too low a heat, some of the cast iron from which it was made may remain in its original condition. In either case a crystalline structure would be shown in a fracture.

It was to the metallurgist almost alone, who knew the advantages of using a metal which has been initially in a fluid condition, and from which, while in this state, all slag and similar impurities have been eliminated, that we owe the present development of the steel industry.

The superior strength of steel and its more perfect homogeneity have driven iron rails and iron structural material completely from the market. It is, however, curious to note that although this change took place from twelve to fifteen years ago, it is only recently that steel has to any great extent superseded wrought iron for forgings, and, as I have already stated, there are at the present day many users of wrought iron forgings who seem to be unwilling to make the change.

Fig. 1\* shows a series of drop tests made on pairs of bars of wrought iron and steel of the same size to compare their relative strength. These tests are reported by Prof. L. V. Tetmayer, in the records of the Test Bureau at Zurich, Switzerland. All the bars were furnished by the well-known works of Wendell & Co., Hayange, Loraine. The chemical composition of the two metals was as follows:

	C.	Si.	P.	S.	Mn.
Wrought Iron . . . . .	'05 to '06	'05 to '15	'30 to '50	'02 to '04	trace
Steel . . . . .	'08 to '12	trace	'03 to '06	'02 to '04	'40 to '70

[The high percentage of phosphorus in the wrought iron was due to the slag.]

The weight of the drop was 661 pounds. The height of fall and number of strokes was as follows:

	1½" square		2¼" square		2½" square		3¼" square		4" square	
	W. I.	Steel	W. I.	Steel	W. I.	Steel	W. I.	Steel	W. I.	Steel
Fall	8'66"	8'66"	18'9"	18'9"	28'35"	28'35"	50'4"	50'4"	78'74"	78'74"
Strokes	2	3	2	3	1	4	1	7	1	6

It will be noted that in each instance the steel bar received more severe treatment than the wrought-iron bar, but with

\*From *Materials of Construction*, J. B. Johnson (Wiley, N. Y., 1897), by permission of the author.

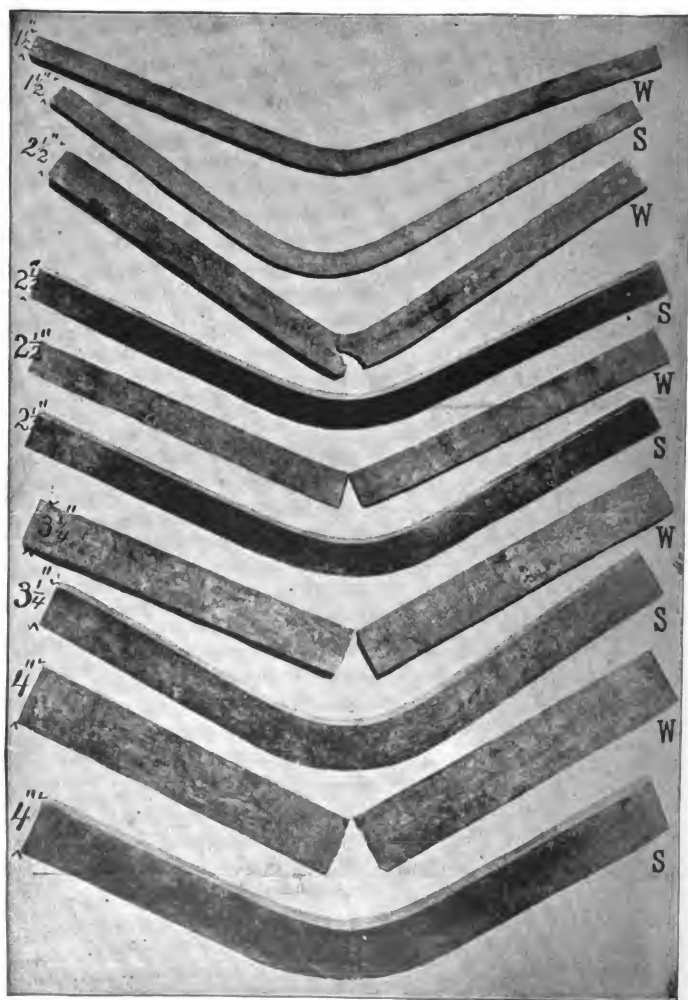


FIG. 1.—Comparative drop tests of wrought iron and steel.

far less damaging results. Do these tests show that steel is more brittle than wrought iron?

Let us look into the reasons for the primal reluctance of the trades to adopt steel for forgings, and see if they are still cogent and a preference for wrought-iron forgings now legitimate.

Going back to the time when the large rolling mills of the country changed their product from iron to steel, we find that the industrial conditions of the country were not such as to demand forgings of any considerable size. The forges then in existence were equipped with small hammers, which, by taking advantage of the property of welding possessed by wrought iron, were of sufficient capacity to build up such small forgings of that metal as were demanded.

As soon, however, as manufacturers knew that there was a new material in the market that was stronger and more reliable than wrought iron, they appreciated that, by its adoption for forgings, they could reduce the size of many parts of their machinery, and at once made a demand upon the forges for forgings made of it.

Had the forges made modifications in their equipment to the same extent that the rolling mills had, in order to meet the requirements of the new material, without doubt satisfactory steel forgings could have been produced. No such changes, however, were made, and such steel forgings as were produced were made under an inadequate understanding of the processes necessary for turning them out.

Steel does not possess to the same degree as wrought iron the property of welding. Instead, therefore, of building up a forging of small pieces, it is necessary to work down the finished piece from a block of steel of considerable size. It should be, in fact, twice its size, in order that the proper amount of work necessary to make it a forging should enter into the metal during its reduction in size by the forging process. For instance, a 12-inch shaft, made of iron, would be built up of small pieces, 4 or 5 inches thick, welded together. For a steel shaft of the same size, on the contrary, best practice would require forging down a piece of steel 24 inches in



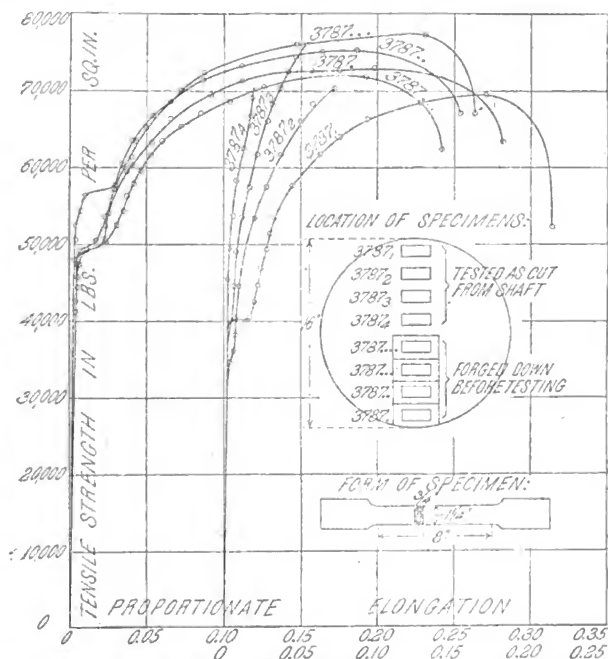
diameter under a hammer whose blow could be felt through 24 inches of metal instead of only 4 or 5 inches.

When, therefore, the manufacturers of the country called for steel forgings, in the first place the forges did not have the hammer equipment necessary to make them, and there were other ample reasons for their not being able to supply them, as will be appreciated when we view the processes which are now considered necessary for turning out good work. Many forges did not hesitate, however, to supply as good steel forgings as they could make with their incomplete equipment, and having so begun, they have continued ever since to supply work of the same character, which has not been, and cannot be, satisfactory, as I think will be made clear as we go further into the subject. The result is that an undefined prejudice has unjustly been established in the trades against steel and in favor of wrought-iron forgings, and it has been kept fresh in the minds of the uninformed up to the present time to a great extent through these forges themselves, who seem to have been unwilling to equip themselves properly for turning out steel forgings.

The diagram, *Fig. 2*, shows a series of tests of the metal of a shaft made at the time of which we are speaking, and shows its condition as the result of attempting to make a large forging under a light hammer.

This shaft, a section of which is shown by the circle, was 16 inches in diameter, and was made for the United States Dispatch Boat *Dolphin*, under a 10-ton hammer from a 30-inch steel ingot, and after it had been in service but a very short time it broke. The broken section was sent to the Government Testing Bureau, at Watertown, to determine, if possible, the cause of failure. Test pieces of the size and shape indicated in the lower part of the diagram were cut out of the upper half of the shaft at varying distances from the center, as shown in the sectional drawing, and were marked respectively 3,787, with subscripts 1, 2, 3 and 4. The results of the tests are shown by the curves bearing their respective markings, and the records can be read in the lower line of figures underneath the diagram. The outer specimen gave an elongation

of 21.4 per cent., the second one of 5.5 per cent., the third one of 4.9 per cent. and the one nearest the center of but 2.0 per cent. In other words, the ductility or toughness of the metal varied from 21.4 per cent. to 2 per cent. between the surface and the center, showing that the former metal only had been



\* FIG. 2.—Graphic representation of effect of forging 16'' steel shaft of U. S. Cruiser *Dolphin* under a hammer of 10 tons falling weight.

worked under the light hammer, while the latter remained in the condition of the original steel ingot. In order to further prove that the failure of the shaft was due to the metal not having been worked sufficiently, and that if it had been worked more thoroughly it would have been tougher, specimens of

\* By permission of Prof. J. B. Johnson.



Fig. 3. Broken 1 1/2" steel shaft forged under hammer of 10 tons, falling weight. Crystalline center of original ingot not affected by influence of flight hammer.

larger size were taken from the lower half of the shaft, as shown, and marked 3,787. — 3,787.. — 3,787... — 3,787.... and these were forged down until they were of the same size as the specimens taken from the upper half. In other words, work was put into the metal of the test bars by forging them down which ought to have been put into the metal of the shaft during the original forging process. The records of these tests can be read in the upper line of figures underneath the diagram. The four bars showed an elongation of 25.4, 28.2, 26.4 and 24.1 per cent. respectively, or an average of 26 per cent., which showed conclusively that the cause of the break was due not to any inherent weakness in the metal, but solely to lack of work in the center metal.

Prof. R. H. Thurston, at a meeting of the American Society of Mechanical Engineers, held in 1886, in this very room, made the following remarks regarding this shaft: "I examined the steel shaft of the *Dolphin*, the United States steamer recently made famous by the unfortunate misunderstanding between Mr. Roach and the Navy Department, which has led us to so strongly sympathize with that enterprising builder of late. I found the section fractured, exhibiting most excellent structure near the surface; but it was very strongly crystalline, apparently, near the center. It had, I judge, been too heavy a job for the hammer available for forging it; the crystals had been produced while heating it, and had not been broken up in forging, in consequence of the fact, I have no doubt, that the effect of the blows could not reach the core. The tenacity of the outer part of the shaft was evidently fully up to the standard; but the center had lost its strength very greatly."

*Fig. 3* shows a 15-inch steel shaft also made about this same time under a hammer of 10-ton falling weight, which was about the heaviest in use in those days and even at the present time is the weight of those used at most forges to turn out their heaviest work. The center shows the crystalline condition of the original ingot, and it is evident that the effect of the hammer was not felt very far below the surface.

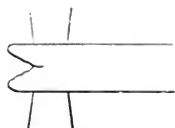


FIG. 4. — Effect of forging under a light hammer.

The effect of the hammer may also be to draw out the surface metal and leave the center behind to such an extent as to cause cracks and even cavities in the latter, which are apt to develop in service and cause rupture. *Fig. 4* shows the appearance of the end of almost all hammered shafts. The drawing out of the surface metal at the end is indicative of what has occurred throughout their length.

*Fig. 5* shows a broken 15-inch steel shaft forged under a 10-ton hammer, which shows very plainly the tearing effect referred to.

The above are some of the defects in steel forgings which have caused their failure in the past and which have tended to prevent their coming into more general use. They are all due to faulty methods of manufacture.

Notwithstanding the prejudice which these defects have occasioned in favor of wrought-iron forgings, manufacturers are beginning to find that the latter are becoming less and less reliable. One reason for this is that the industrial condition of the country has changed so as to demand larger forgings. Another reason is that as the change from iron to steel is becoming more and more complete throughout the country, the supply of wrought-iron scrap is getting gradually less and steel scrap more plentiful, and as there is no way of distinguishing these metals apart in rapid handling, it is with difficulty that pieces of steel scrap can be prevented from becoming incorporated in wrought-iron forgings. Whenever this occurs, the two metals do not weld satisfactorily, and points of weakness are occasioned which eventually lead to fracture. *Fig. 6* shows a wrought-iron shaft broken from this cause. The piece of steel can be seen projecting from the section of shaft in the foreground.

Many failures of forgings in the past, which were the direct results of improper manipulation in manufacture, have been attributed by the uninformed to the "crystallizing effect of shock" or to "fatigue of metal from alternating stresses" in service, particularly when the failures occurred to such forg-



FIG. 5.—Broken 15" steel shaft forged under hammer of 10 tons falling weight. Piped center of original ingot enlarged and metal torn by surface impact of light hammer.

ings as steam-hammer rods or to connecting- and piston-rods and crank-pins.

Since this time, however, we have learned more about both iron and steel than was then known, and although our knowledge of the subject of "fatigue of metal" from the effect of alternating stresses is still limited, we do know that these metals, being initially crystalline, do not become so from shock or other similar service when cold. We have also so far advanced in our methods of manufacture that we are now able to make forgings entirely free from the defects above noted, and which, if properly designed, will, when subjected to service of the character mentioned, last a very long time.



FIG. 6.—Broken wrought-iron shaft of Lake Steamer, showing piece of steel scrap in center.

What is this "fatigue of metal" of which we have heard and still hear so much? What is this mysterious cause to which so many failures in the past have been indiscriminately charged? Let us see what investigations into the subject have been made and what has been learned from them.

We find that, as far back as 1871, experiments were reported by Wöhler, in Germany, followed by Spangenberg and Martens and Bauschinger. In England the subject was similarly reported upon in 1886 by Mr., now Sir Benj. Baker, in his records of tests of material for the Forth Bridge, and it has

since been pursued systematically in this country by Mr. Jas. E. Howard, at the Government Testing Bureau, at Watertown. And after all the time and labor that has been devoted to the subject, what information has been derived? Simply that iron and steel are more amenable to the laws of the universe than we had previously given them credit for. That the same laws under which "continuous droppings will wear away a stone" are applicable to these metals. That frequent repetitions of load in amount far below the ultimate strength of the material will eventually break down its resistance and cause failure.

Beyond the bare statement of the above fact, laws of a general character have been formulated, but the complex nature of the situation prohibits exactness.

If we apply the same conditions to animate things, the results do not seem out of the ordinary. A good horse can, under favorable conditions, pull a load of several tons weight up a steep hill without serious discomfort. Compel him, however, to pull even one-tenth of the load up the same hill many times each day, week after week, and it would be only a question of a few months before his strength would give way.

No two pieces of metal are alike in chemical composition, and, if they closely approach similarity in this respect, the difference in mechanical treatment during their manufacture causes them to possess widely different physical properties.

Generally speaking, however, we now know that for any given stress a certain number of repetitions produce failure, the greater the intensity of stress, the smaller the number of repetitions. We know also that the stress required to cause failure is less, and roughly speaking only half as great when the metal is strained alternately in opposite directions, as where it is strained in one direction only.

Let us, for instance, submit a bar of steel or iron to 30,000 pounds per square inch tensile, or to 30,000 pounds per square inch compressive stress. In either case the "range" is the same, viz.: 30,000 pounds. Now let us subject the bar to 15,000 pounds per square inch tensile and to 15,000 pounds



per square inch compressive stresses alternately, and, although the range is 30,000 pounds as before, the life of the material thus strained will be only half as long, although neither the tensile nor compressive stress approaches the elastic limit of the metal as closely as in the first two cases.

It is in fact very striking how regularly progressive the increase in the number of repetitions is as the range of stress decreases. In other words, the less the metal is maltreated, the longer it will endure, and, if we can make the range of stress small enough, a practically unlimited number of repetitions is required to cause failure. In "endurance tests" of this character, Wöhler found that the rupture of a bar of wrought iron by *tension* was caused by any of the following ways:

by	1 application	of 55,000 lbs. per sq. in.
"	800 applications	" 51,500 " " "
"	107,000	" 47,000 " " "
"	341,000	" 42,500 " " "
"	481,000	" 38,000 " " "

a piece of spring steel, subjected to *bending*, broke as follows:

under	81,000 applications	of 95,000 lbs. per sq. in.
"	154,000	" 85,000 " " "
"	210,000	" 75,000 " " "
"	472,000	" 65,000 " " "
"	539,000	" 58,000 " " "
"	1,165,000	" 53,000 " " "

The apparatus used to make tests of this character is shown in its simplest form in *Fig. 7*. It consists of an ordinary lathe bed specially fitted at the driving spindle *n*, with a ball and socket chuck *j*. A habbitted box *k*, mounted on trunnions, is fitted to the other end of the bed. One end of the bar to be tested is screwed into the ball *i*, which is pressed against the face of the chuck by a helical spring *o*; the other end rests in the box *k*. A loose bronze flanged ring *b*,  $\frac{1}{2}$  inch wide, fits on the bar at its middle. A weighted lever, *d*, rests on this ring through the friction wheels *c*. The ratio of the arms of the lever is as 3 to 1. The fiber stress on

the bar can be regulated by varying the weight suspended at the end of the lever. By rotating the weighted bar through the driving spindle of the lathe, every fiber is subjected to bending alternately in opposite directions.

Thus conditions are imposed on the metal imitating those which occur in actual practice in such machine parts as railway axles, engine shafts, crank and crosshead-pins, etc., where the fibers of the metal are subjected to stresses, continually varying from tension to compression.

The testing of metals to determine whether they possess specified physical properties is customary in order that a grade or quality may be obtained to meet the requirements of the service for which they are intended. For this purpose, certain simple and rapid standard tests have been determined upon in practice, to obtain respectively the maximum tensile, compressive and transverse strength of materials. It has been found from these that within a certain limit, which is approximately one-half of the ultimate strength, the metal is elastic, and if strained beyond this point its working strength

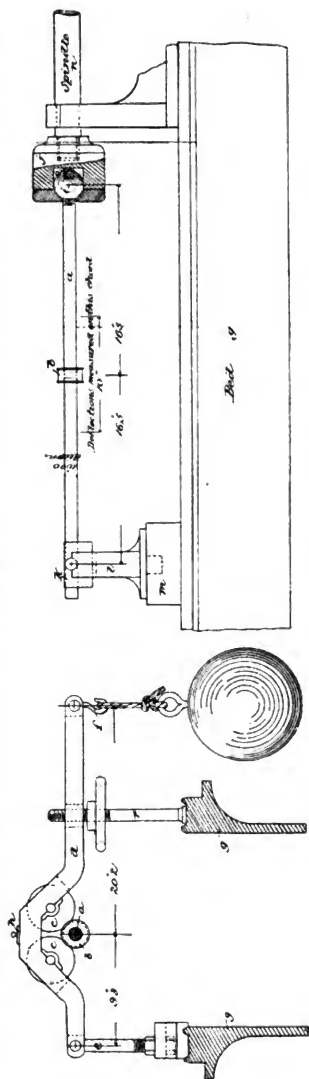


FIG. 7.—Apparatus for endurance tests of rotary shafts used at Watertown Arsenal.

is exceeded and it can no longer be depended upon to sustain even minor loads. Such tests give results, however, which are simply relative. Their actual significance is uncertain. The fact that a metal possesses a certain elastic limit, elongation and contraction of area when ruptured by once loading, fails to convey an adequate idea of what the same metal will do under circumstances of repeated stresses or when these stresses are applied in alternate directions, as they are in practice. Endurance tests, therefore, have been made with great care in connection with the usual standard tests above mentioned, in order to determine the relations that exist between the two.

From a careful comparison of these relations, knowledge is obtained so that through a determination of the qualities of metal by the standard tests, a prediction can be made of the conduct and endurance of the same metal in an actual service, analogous to that in the endurance test, which is a long and expensive one, and, therefore, impracticable for use in commercial work.

The speed at which the testing machine is operated varies according to conditions, but generally bars of very high tensile strength are rotated rapidly, in order to obtain results within a reasonable time. Sometimes the speed of rotation is as high as 2,200 per minute. At this speed stresses alternate from tension to compression at an interval of a little less than one-thirty-sixth of a second, or in passing from a neutral state of stress to the maximum tensile or compressive stress, the time occupied is about one-seventy-third of a second.

On starting the machine, if the bar is bent by the weight so as to cause considerable alternation of stress, a decided resistance to rotation is offered and the deflection decreases noticeably. After running for a short time, however, the molecules of metal seem to move more readily on each other and the original deflection is resumed.

In general, the molecular movements are not checked under the highest speed of rotation if the stresses are below the elastic limit. If this is exceeded, however, the deflection is less at high than at low speeds. Apparently, there is not time enough allowed to perform the work against molecular

friction and to complete the bending movement. In this case there is a rapid elevation of temperature. As this latter tends to prolong the life of the bar and as it is not obtained by any service in actual practice, the bar is rotated in cold water to keep the temperature as nearly constant as possible.

The following differences are noticed between steel bars run at temperatures of about  $475^{\circ}$  and  $70^{\circ}$ :

15 per cent. carbon, hot, 85,200 revolutions; cold, 4,350 revolutions.

34 " " " 127,700 " " 11,600 "

73 " " " 218,500 " " 34,900 "

The following table gives the relative endurance of a series of bars of varying carbon, from the Bethlehem Iron Company, tested under a fiber stress of 40,000 pounds, which is below the elastic limit of all the specimens tested and is actually less than one-half of that of the strongest:

TABLE No. 1.

Specimen.	Tensile Strength.	Elastic Limit.	Extension in 2 inches.	Contraction.	Number of Rotations.
24c. annealed	{ 71,240 72,100	40,560 41,200	32'3 31'1	59'81 60'32	229,300
24c. hardened	{ 74,440 73,930	45,170 44,150	33'15 31'00	69'93 70'19	348,000
42c. annealed	{ 80,855 86,410	44,290 47,040	23'00 26'6	56'7 51'63	225,900
42c. hardened	{ 92,180 89,990	55,000 53,170	26'05 26'8	57'22 59'88	655,600
46c. annealed	{ 94,600 98,180	48,060 48,060	21'15 21'6	47'65 39'53	976,600
46c. hardened	{ 102,850 104,400	61,110 62,130	23'05 22'5	51'27 50'42	1,657,500
66c. annealed	{ 124,200 127,720	65,205 65,920	7'15 11'95	17'28 20'54	3,689,000
66c. hardened	{ 154,920 153,380	92,040 92,040	13'5 13'05	31'48 30'15	4,323,600

The effect of the carbon content is conspicuous both in the standard and endurance tests.

Following are the results of tests on bars broken from time to time during the past few years at the Watertown Arsenal. The records of the wrought-iron bars are the average of a large number of tests:

TABLE No. 2.

Fiber Stress, lbs. per square inch.	40,000	35,000	30,000
	Rev's.	Rev's.	Rev's.
Wrought Iron	59,000	175,000	625,000
'16 per cent. C. Steel	{ 193,000 170,000	763,000	
'17 " " "	162,000	970,000	
'34 " " "	{ 317,000 236,000	14,100,000	
'55 " " "	160,000	3,609,000	
'73 " " "	454,000	15,290,000	12,548,000
'82 " " "	{ 270,000 481,000	13,900,000	16,300,000
1'09 " " "		19,150,000	{ 50,000,000 not ruptured.

These results, which are representative of many, show that the material, after a certain number of repetitions of stress, breaks with a fewer subsequent repetitions. It is impossible not to conclude, whatever the cause of decreased life of the bar may be, it is a cause which acts continuously, altering in some way its structure or properties.

A man of seventy years of age may be as sound as he was at twenty; but the fifty years have told on him nevertheless, and the breakdown is certainly near and may be sudden.

It would naturally appear likely that any gradually progressive alteration or fatigue of the bar would be manifested in some way in alteration of the ultimate strength, elastic limit or elongation of the bar, when tested in the ordinary way. This, however, does not appear to be the case. A bar subjected to so many repetitions of loading that it is known to be on the point of breaking, or a piece of bar already broken in an endurance test, gives in the ordinary testing machine no indications that its strength or ductility has been altered.

Specimens taken from the center of the bar, where the treatment has been most severe, show a higher tensile strength than those taken from the ends. This fact has led Mr. Howard, of the Watertown Arsenal, to suggest that possibly the effect of this treatment is similar to cold working the metal; that

ordinary, hot-worked metal is not left in its state of greatest tensile resistance, and that while repeated alternate stresses below the ordinarily accepted tensile strength eventually cause rupture, the metal in an intermediate stage passes through a state of increased resistance. He thinks we are not certain, when final rupture occurs, that the parts first to yield are not at the time in a state of maximum resistance, and the apparent loss in strength may be due to the accumulation of internal strains. Such speculations are extremely interesting and may lead to results that will be valuable. For the present purpose, however, we must confine ourselves to known facts. One of the principal of these is that the fracture of these bars is not crystalline. Usually, one-half of the specimen seems to have yielded first, and the metal there has the appearance of having worked upon itself, and has a dull leaden color, the other part has a fine granular structure. The left-hand side of *Fig. 8* shows a shaft which has broken from fatigue and has this characteristic fracture.

I might say that the concurrence of evidence from bars broken by fatigue, both in actual service and in the testing machine, is to the effect that there never has been a case found where it was known or could be demonstrated that any change in structure had taken place. And this goes to prove that materials of this kind are incapable of cold crystallization when exposed to the conditions of service mentioned.

Careful consideration of the results of endurance tests so far made leads to the recommendation of material for forgings which shall have a very high elastic limit and be so proportioned, if they are to be subjected to frequently alternating stresses, that these stresses shall at all times lie far within this limit.

In order to insure these two points, steel, not wrought iron, should be the metal used, and the higher the carbon content of the steel, the longer will be its life, other things being equal.

High carbon steel forgings, sound and free from internal strains, are by no means easy to produce. Much time and thought have been expended to devise methods for making

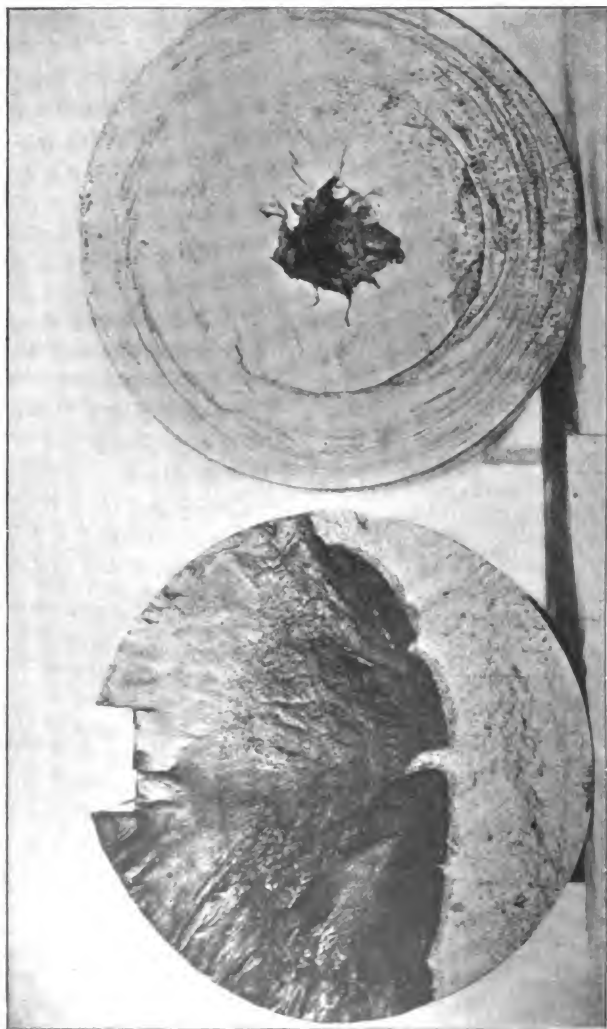


FIG. 8.—Left-hand section shows a 12" steel shaft broken from fatigue of metal. Right-hand section shows pipe in center of 12" steel shaft not closed up under hammer of 10 tons falling weight.

them and much money has been invested in fitting up the necessary apparatus. In order to have thorough supervision and control of every process, complete chemical and physical laboratories should be adjuncts of every forge that expects to do conscientious work. Records should be kept of the treatment of each forging as it progresses from one stage to another.

Let us run rapidly through the various processes which are now considered best practice in making steel forgings of high grade, and see if they overcome the defects which I have shown to have been so common in the past, and if they are tending in the right direction to meet the endurance which we have just seen is required of them in service.

Having carefully considered the service to which a proposed forging is to be put, the charge of raw material for the furnace is made up so that the finished product will have the proper chemical composition, which, from previous experience, is found to be most satisfactory. The elements, carbon, manganese, silicon, phosphorus and sulphur, all have an influence bearing not only on the working of the metal in the shops, but upon the strength of the forging in subsequent service.

[ *To be continued.* ]



THE HOLOPHANE GLOBES, FOR EFFECTING THE  
BETTER DIFFUSION AND DISTRIBUTION OF  
ARTIFICIAL LIGHT.

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*[Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the invention of Messrs. Blondel and Psaroudaki of Paris, France.]*

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[No. 1,945.]      HALL OF THE FRANKLIN INSTITUTE,  
PHILADELPHIA, October 6, 1897.

The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through the Committee on Science and the Arts, investigating the merits of Blondel and Psaroudaki's Holophane Globes, submits the following report:

The invention submitted for investigation is one that pertains to the diffusion and distribution of light by means of a globe or shade placed around the source of the light.

The object of the invention is to secure diffusion of the light as well as such a form of distribution, that the light, usually lost by being sent off into the space above the horizontal plane passing through the source of the light, shall be distributed in the space below that plane and thus be made useful.

In order to secure these results, the principles of reflection and refraction are employed, and such a form is given to the contour of the globe as to make these principles available.

Whenever a beam of light strikes upon the surface of a medium that is not opaque, there are three physical results, namely, reflection, absorption and refraction.

In the globe under consideration, reflection and refraction are made use of to secure diffusion and distribution, and as the globe is made of a transparent material, the amount of absorption—which represents a loss—is reduced to a minimum.

The interior surface is made of a continuous series of vertical flutings, as is shown by *Fig. 1*, which represents a horizontal cross section through the middle of the globe. The function of these flutings is to secure a distribution normal to the direction of the incident light. This is practically in a

horizontal plane from a belt extending  $15^{\circ}$  to  $20^{\circ}$  on each side of a horizontal plane passing through the source of the light. The general character of this distribution is shown in *Fig. 1*.

Theoretical considerations require that the curve formed by the intersection of this inner fluting by a horizontal plane

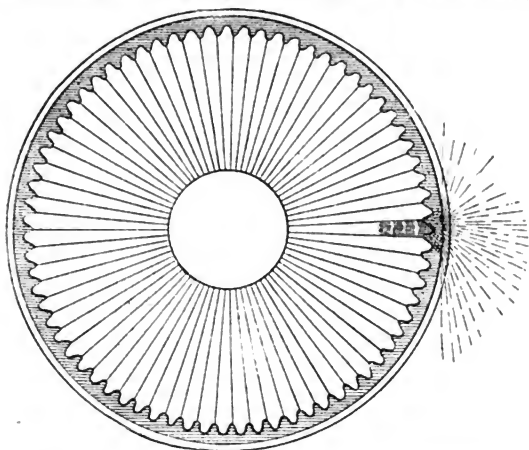


FIG. 1.—Horizontal (center) section of holophane globe.

should be a curve both convex and concave to the inside of the globe, the concave portion being about two-thirds the width of the curve, and that the angle made by two sides of adjacent grooves should be about  $30^{\circ}$ . Both of these requirements are met in the construction of the holophane globe, and hence the desired horizontal distribution is obtained.

An enlarged horizontal cross section of the inner fluting is shown in *Fig. 2*.

The external surface of the globe is made up of a series of circular grooves in a horizontal plane, extending over the entire surface of the globe.

In order to secure the best distribution of the light, each

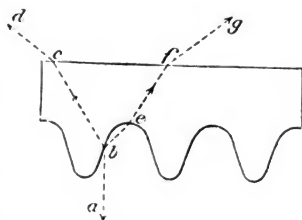


FIG. 2.

groove should, theoretically, be constructed according to the principles of geometrical optics, with reference to the relative position of the groove and the source of light. The method of determining the profiles of these grooves and ribs is as follows: The general contour of the globe and the location and size of the light source being determined, a number of points are taken at equal or approximately equal distances on the periphery, as shown in the left side of *Fig. 3*. Rays are drawn from the top and bottom points of the light source to these points, and the faces of the prisms are calculated geometrically to dis-

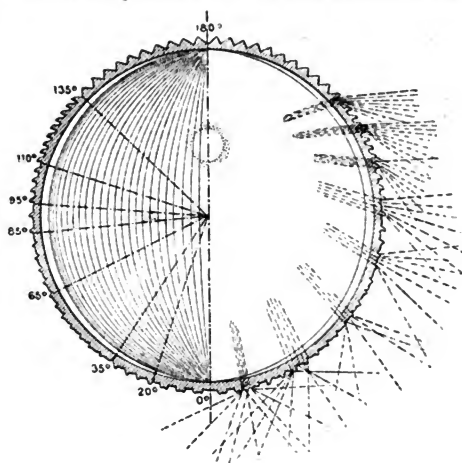


FIG. 3.—Vertical section of holophane globe.

tribute the beam or cone of light in the most advantageous manner. The profiles of the prisms between these points are determined by interpolation. *Fig. 3* shows a vertical section of the globe, the left side showing the division into bands spoken of above, and the right side showing their effect upon distribution in a vertical plane.

The general design of the external grooves is shown in vertical cross section in *Fig. 4*. The external part of this section is seen to consist of four faces.

The face, *a b*, serves to throw the beam falling upon it below its original direction by refraction. The beam falling upon the face, *b c*, strikes at a greater angle than the critical angle, and hence is reflected downward and passes out the face, *d e*, where it is variously distributed by refraction.

The face, *c d*, serves the same purpose as the face, *a b*, but as the beam strikes it at a different angle it passes out in a different direction. The opinion of the investigating committee, after having examined the theory of construction of the globe, and after having studied the results obtained from it, is that the inventors have succeeded in making such a combination of inner grooves, giving horizontal distribution by refraction, and mixed outer grooves giving vertical distribution by both refraction and reflection, that both diffusion and an improved distribution are satisfactorily obtained.

Upon examining the distribution of light by this globe, the investigating committee found that when the light from an arc lamp passed through the globe the effect upon a vertical screen showed a distinct cutting down of the amount of light passing in a straight line through the upper part of the globe and a definite increase of the light on a horizontal plane, and at all angles below that plane, the space vertically beneath the globe being well illuminated.

The fact that diffusion is secured is shown by the character of the shadows cast. When an opaque body is held near the globe there is practically no shadow on a screen a few feet away. As the body is moved toward the screen, a faint shadow having very indistinct outlines is thrown upon it.

This property of the globe has the effect of entirely doing away with distinct shadows of bodies near it that is so objectionable in the ordinary arc light.

In appearance the holophane is covered with bright points over its entire surface. Each one of these points is a source of

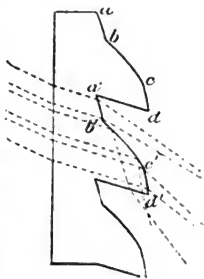


FIG. 4.

light, sending out its rays uniformly distributed, and since the number of these brilliant points is very great, covering the entire globe, the light coming from its surface is diffused.

Recent tests made by Prof. Lewes, of London, on the distribution of light from a Welsbach burner through different globes, as reported in the *Progressive Age* for December 15, 1896, show that in the angle between the horizontal plane and  $45^{\circ}$  below it, the use of the holophane globe increased the light from 12 per cent. to 13 per cent., while the best of a number of other globes examined gave a loss of 7.5 per cent. for a clear glass globe without any diffusion.

As a result of an examination into the construction of this globe, and an investigation into its practical working, the committee intrusted with this investigation believes that Messrs. Blondel and Psaroudaki have invented a globe that secures much better diffusion and more satisfactory distribution than any other globe known to its members; that the conditions of its manufacture are such that it can be supplied to the trade in commercial quantities; and that the invention has secured a distinct improvement in the diffusion and distribution of artificial light.

The Franklin Institute, for the reasons above stated, recommends the award of the John Scott Legacy Medal and Premium to Messrs. Blondel and Psaroudaki for their invention.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, November 3, 1897.  
Award approved by the Board of Directors of City Trusts.

JOHN BIRKINBINE, *President.*

WM. H. WAHL, *Secretary.*

Countersigned,

JAMES CHRISTIE,

*Chairman of the*

*Committee on Science and the Arts.*

## NOTE.

The above invention has been patented by André Blondel and Spiridion Psaroudaki, both of Paris, France, as follows:

Germany, March 16, 1893. No. 78,866.

France, September 30, 1893. No. 233,140.

England, October 12, 1893. No. 19,185.

Austria-Hungary, January 6, 1894. No. 48,988.

Belgium, March 13, 1895. No. 108,985.

United States, July 14, 1896. No. 563,836.

The committee of investigation, in its work, took occasion to refer to the above United States patent, to a paper entitled "Public Lighting by Arc Lamps," by André Blondel, Paris (pages 40-60); to the typewritten notes of a lecture by Prof. Elliott, of Pittsburgh, Pa., and to the *Electrical World* of January 2, 1897 (page 25).

The thanks of the Investigation Committee are due to Superintendent Mainwaring, of the Brush electric lighting station, through whose courtesy a comparison of the holophane with other globes was made.

## SUPPLEMENTARY DATA.

The following brief abstract of the results of the experimental investigations of Herr H. Drehschmidt, chemist to the Municipal Gas Works of Berlin, is appended, partly because of their general value and interest as a contribution to the subject of modern methods of distributing light and partly as confirmatory of the conclusions reached in the foregoing report.

The work of Herr Drehschmidt was lately published in the *Journal für Gasbeleuchtung*,\* under the title, "The Distribution of Light from Welsbach Burners when Used Alone, and when Used with Holophane and Diffusor Globes," and gave the results of his experiments to date, with the cause of the unexpected inefficiency of the Welsbach lights, installed on one of the principal thoroughfares of Berlin, in respect of uniformity of light diffusion. The author devised ingenious apparatus to

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\* See *Jour. f. Gasbeleuchtung*, Nov. 21, 1896.

measure in various planes this apparent irregular distribution, and made certain experiments with the "holophane globes" and other related devices for correcting the inherent defect of the Welsbach light. The abstract of this work herewith reproduced is confined to the comparative exhibit made by the naked lights, and the same provided with the holophane globes, viz.:

"When the Stralauer-Strasse, Berlin, came to be lighted with incandescent gas lamps the result was, in spite of the high candle-power of the lamps, that the lighting made no great impression of brilliancy; the street pavement seemed, on the contrary, to be rather dark, and only the walls of the houses at the level of the lamps were brightly lit up.

"It may, perhaps, be the case that the green tint of the Welsbach light is not absolutely negligible, but the principal cause must be looked for elsewhere. On the other hand, the light radiating from a Welsbach burner is not equally distributed in all directions, taken with reference to a horizontal plane passing through the burner, and underneath the burner it is distributed in a fashion which is unduly unfavorable to the purpose of illumination. Furthermore, it was found that the reflectors used in the Stralauer-Strasse lamps contributed little towards making up for this defect in the Welsbach light.

"In the laboratory of the Municipal Gas Works in Berlin investigations have been made for some considerable time past with regard to the distribution of light from incandescent burners, both when used alone and with the aid of globes and reflectors. In these investigations I used by preference a mirror-reflecting apparatus specially designed by myself.

"The light radiating from the burner at different angles strikes a mirror, invariably at  $45^{\circ}$ , and is reflected horizontally along the axis of the photometer. The burner can be brought into all the different required positions by the simple turning of an arm, and it remains through this means at a uniform distance from the mirror, which moves at the same time as the burner does. The light passing downwards can be measured at all angles from  $0^{\circ}$  to  $90^{\circ}$  with the horizontal; that passing upwards can only be measured as far as  $80^{\circ}$ , since at an angle

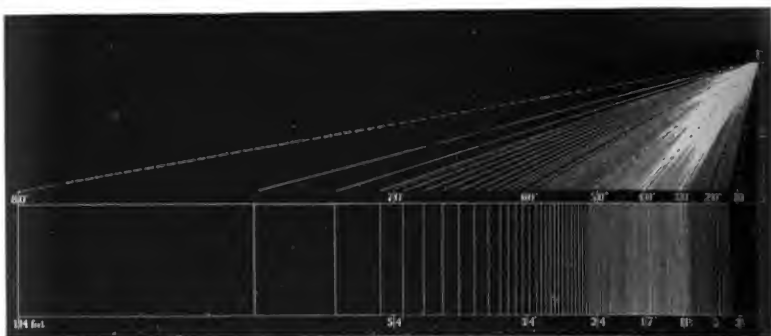


FIG. 5.—Bare arc lamp.

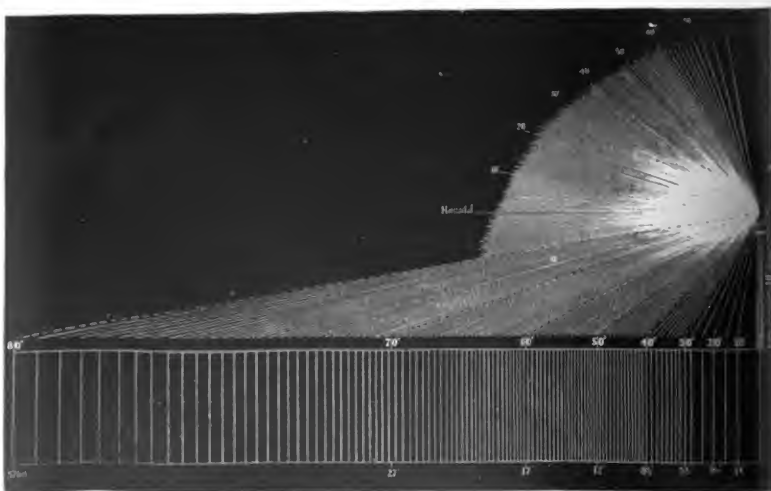


FIG. 7.—Bare Welsbach.



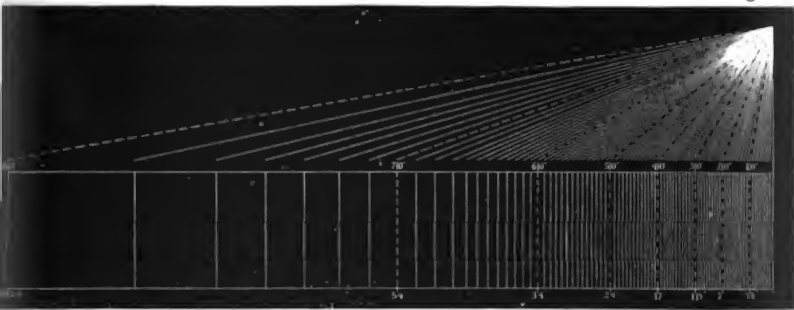


FIG. 6.—Holophane globe on arc lamp.

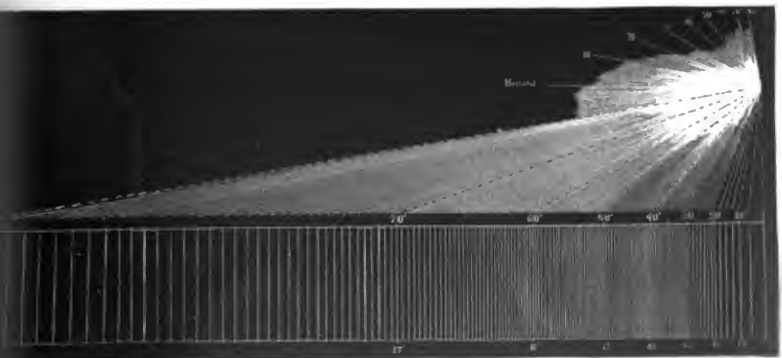


FIG. 8.—Holophane globe on Welsbach.

of  $90^\circ$  with the horizontal the burner would be directly under the mirror, and the latter might probably be damaged by the hot gaseous products of combustion. The light sent upwards between  $80^\circ$  and  $90^\circ$  is, however, so small that even to neglect it altogether makes very little difference in the aggregate result. The measurements made with this apparatus take scarcely any more time and trouble than the ordinary photometric measurement of light in the horizontal direction.

"The incandescent gas burner used in these researches came from the German Incandescent Gas Light Company (Welsbach), and it gave, when fitted up with a fresh mantle from the same company, a light of eighty-five English standard candles (ninety-eight Hefner units)\* after two hours' use, and of seventy candles (eighty Hefner units) after thirty hours' use, all at a pressure of twenty-five millimeters (0.984 inch), and a gas consumption of 3.638 cubic feet per hour. Since the illuminating power of the incandescent gas light was not constant, but diminished continuously as time went on, it was necessary, in order to make the results of different investigations comparable with one another, to set down in every case the illuminating value of the bare Welsbach lamp taken in a horizontal direction, as 100, and to state the values in other directions proportionately to this.

"By a bare Welsbach lamp is meant the Welsbach lamp without globe or reflector. Table A shows that there is a continuous decrease in the luminous intensity as we pass into the different directions lying below the horizontal plane of the lamp, and this decrease is more rapid the more nearly we come vertically under the lamp. Vertically under the lamp it is almost dark, for there the intensity falls to only 0.4 per cent. of what it is at the same distance horizontally. Above the horizontal plane the distribution of light is very similar, but the decrease is far smaller. The results show that the greater part of the light produced is sent upwards to about  $20^\circ$  above the

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\* One English standard candle = 1.14 Hefner units; the Hefner unit being the light of a standard lamp devised by Von Hefner-Alteneck, the fuel used in which is acetate of amyl. This is the standard now mostly used by the German gas engineers.

horizontal plane. In street lamps this light cannot be utilized in a downward direction by means of the ordinary reflectors. In order to be able conveniently to take off the glass chimney to clean it the reflector cannot be placed as low as would be necessary in order to catch the rays traveling at an upward angle of  $30^\circ$ , and thus about one-third of all the light produced by the lamp is completely lost for the purpose of street lighting.

"The rapid diminution of lighting power as we come under-

TABLE A.

ANGLES MEASURED FROM THE HORIZONTAL	BARE LIGHT	WITH HOLOPHANES (COMPOUND PRISMS)				
		TULIP NO.1	TULIP NO.2	CONE NO.3	CONE NO.4	GLOBE NO.5
0°	100.0	90.7	123.9	104.6	113.5	70.3
10°	96.2	99.8	119.7	106.3	116.3	91.8
20°	88.4	105.6	100.6	98.8	104.2	109.5
30°	77.0	104.3	90.0	88.1	85.1	110.4
40°	63.3	94.8	68.2	75.5	63.3	94.9
45°	58.6	87.1	59.0	66.1	51.9	84.2
50°	50.6	78.7	50.8	60.5	47.2	74.0
60°	32.4	62.1	40.3	46.6	43.9	58.8
70°	14.3	48.9	31.8	40.8	43.2	48.2
80°	3.5	40.9	29.8	40.8	40.1	48.2
90°	0.4	33.2	23.7	33.1	28.9	44.1
10°	99.7	70.5	95.3	100.4	101.0	63.6
20°	98.3	39.7	44.8	65.0	62.4	60.8
30°	90.5	34.3	26.7	29.6	29.1	43.6
40°	82.7	27.7	26.5	25.3	25.9	40.0
45°	75.4	28.2	27.2	27.7	31.0	35.9
50°	70.9	30.6	54.3	32.2	39.8	31.4
60°	58.8	46.1	56.9	48.6	55.3	31.5
70°	42.4	66.6	61.1	33.4	61.5	38.9
80°	30.0	56.5	51.9	43.0	48.1	55.1

neath the Welsbach lamp, which is peculiar to this lamp, is not astonishing when we consider that the mantles, after a very short time, assume a form which is smaller above, and that any light sent from the upper portions of the mantle is obstructed in its path downwards by the wider lower portions. There are similar phenomena, however, even in the Argand flame.

"Herr Polis, of Aix, recently drew attention in the *Journal*

*für Gasbeleuchtung* to holophane and diffusor globes as good means of distributing light. I obtained, through the German Incandescent Gas Light Company (Welsbach), a number of holophane globes from the French Holophane Lighting Company, as follows:

"No. 1.—Tulip shaped, 150 millimeters (= 5.90 inches) high and 135 millimeters (= 5.42 inches) broad, with an upper opening of 125 millimeters (= 4.92 inches) and a lower of 56 millimeters (= 2.20 inches).

"No. 2.—Tulip shaped, 145 millimeters (= 5.71 inches) high and 140 millimeters (= 5.51 inches) broad, with an upper opening of 130 millimeters (= 5.12 inches) and a lower of 56 millimeters (= 2.20 inches).

"No. 3.—Cone shaped, 130 millimeters (= 5.12 inches) high and 110 millimeters (= 4.33 inches) broad, with an upper opening of 100 millimeters (= 3.94 inches) and a lower of 56 millimeters (= 2.20 inches).

"No. 4.—Cone shaped, 110 millimeters (= 4.33 inches) high and 105 millimeters (= 4.14 inches) broad, with an upper opening of 95 millimeters (= 3.74 inches) and a lower of 56 millimeters (= 2.20 inches).

"No. 5.—Globe shaped, with a diameter of 165 millimeters (= 6.50 inches), an upper opening of 76 millimeters (= 2.99 inches), and a lower opening of 56 millimeters (= 2.20 inches).

"The holophane globes develop a revolution in the distribution of the light from a Welsbach burner, as is shown by Table A, as well as by the graphic diagram hereto appended. On the whole, more light comes downward than goes upward; besides this, there is better distribution of light downwards instead of to one side; and even directly under the burner the intensity of the light is considerably increased. With the tulip-shaped holophane the amount of light passing downwards below the horizontal plane is increased by 29 per cent. as compared with the bare Welsbach lamp, and with the other holophanes from 17.2 to 26.9 per cent. The light passing upwards has, on the other hand, been diminished from 28.5 to 42.0 per cent. The total loss by absorption and reflection is thus very small, being only from 7.7 to 9.8 per cent."

In conclusion, attention is called to accompanying diagrams, *Figs. 5 to 8*, showing the distribution of light on vertical and horizontal planes from a direct current arc lamp and from the Welsbach light.

The figures used for the arc lamp are those given by Blondel.\*

The figures used for the Welsbach light are those given by Drehschmidt in his article on the "Utilization of the Welsbach Light," in the *Journal für Gasbeleuchtung*, previously cited.

The quantity of light given out within the angles was determined by the formula

$$Q = (\sin. i_2 - \sin. i_1) (i_1 + i_2)$$

as used by Drehschmidt. The number of lines drawn within the angles is proportionate to the quantities of light thus determined; the lines thus represent rays of light or "pencils" of equal intensity. The space where they run together, showing clear white, is approximately the curve of vertical distribution, corresponding to the one given by Blondel.† W.

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## THE ALL-WROUGHT STEEL PULLEY.

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[*Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the invention of Thomas Corscaden, of Philadelphia.*]

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[No. 1,961.] HALL OF THE FRANKLIN INSTITUTE,  
PHILADELPHIA, June 1, 1897.

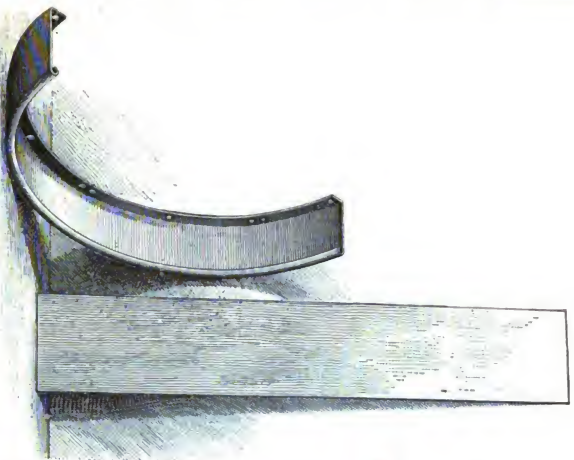
The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of Corscaden's "All-Wrought Steel Pulley," reports as follows:

The all-wrought steel pulley designed and the manufacture

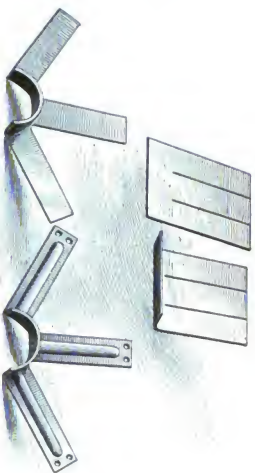
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\* See "Public Lighting by Arc Lamps," pp. 48, 50 and 51.

† *Ibid.* See *Fig. 50*, p. 45.



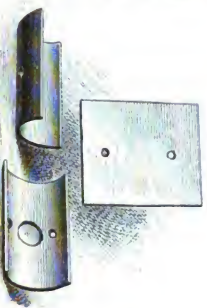
Blank and rim finished.



Making the spider or arms.



Spider finished.



Hub.

Making the Coriscaden all-wrought steel pulley.



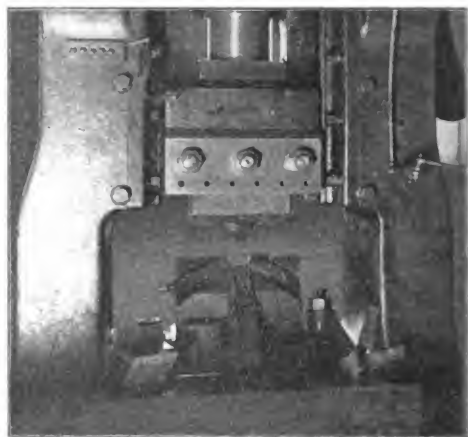
Pulley finished.



One-half of pulley.

thereof perfected by Mr. Thomas Corscaden, of the city of Philadelphia, is protected by letters-patent to the inventor as follows: Nos. 474,546 and 474,547, May 10, 1892, and Nos. 575,106 and 575,107, January 12, 1897.

The pulleys are made in halves, and are such as are usually called split pulleys. They are made up from a number of parts of sheet steel cut from rolled plates. The rim is made in four



Die for convexing the spiders.

parts. The plate is cut up into long strips, the length of which is equal to one-half of the circumference of the pulley and the width equal to one-half of the width of the face plus an amount required to form a bead-moulding on the outer edge of the pulley and a flange web in the center of the pulley. Two of these plates are placed in the dies of a large hydraulic press, where a complete ring (in two halves) is formed, having a cylindrical bead all around the outer edge of the plates and a web



Rim Clip.

flange on the outer edge. Two of these rim portions are placed back to back and riveted together through the web flange; then two of these pairs are brought together and are held in position by dowel-pins

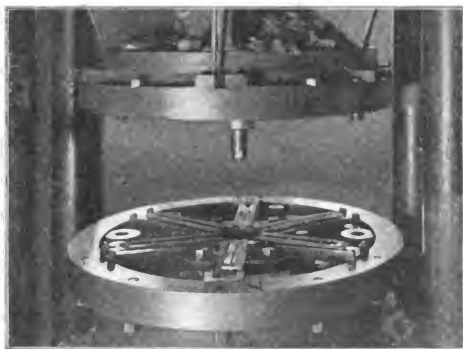
firmly fastened in the cylindrical mouldings at the edges, thus forming the complete rim of the pulley.

The spokes and hub are likewise formed in four parts; they are also cut from thin plates and are split part of their length into three parts, and the part that is not split turned at a right



Clip for holding pulley sections on shaft.

angle, which, after being perfectly formed, makes the hub. These parts are also placed in the hydraulic press, where they are compressed into form, making part of the hub with three half spokes. The half spokes have a conical groove pressed in them to stiffen them, and when two of these plates are placed



Die for forming the corrugations in spiders.

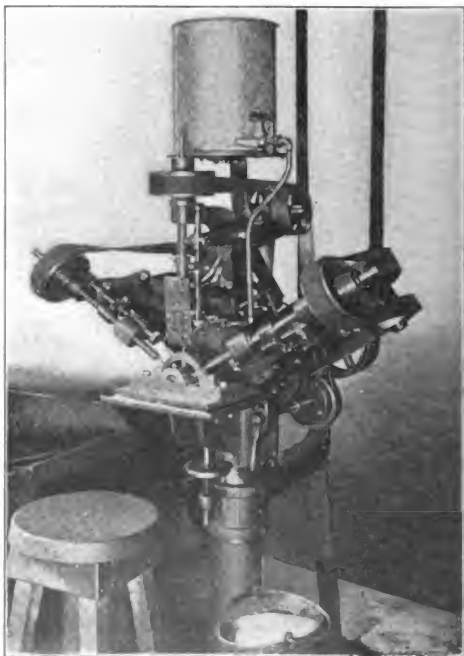
together and riveted they form a spider composed of one-half of the hub and three completed spokes; then the three spokes of the spider are riveted to the inner web of the rim, and thus one-half of the pulley is formed.

Cylindrical clamps are riveted to the web at both ends of



the section. The halves of the pulley are now placed together and firmly secured by bolts passing through the cylindrical clamps. They are held firmly in circular alignment by the dowel-pins fastened in the bead moulding at the edges of the rim.

The hub is completed by cutting clamps from the plates of



Machine for drilling spiders and hub-shells.

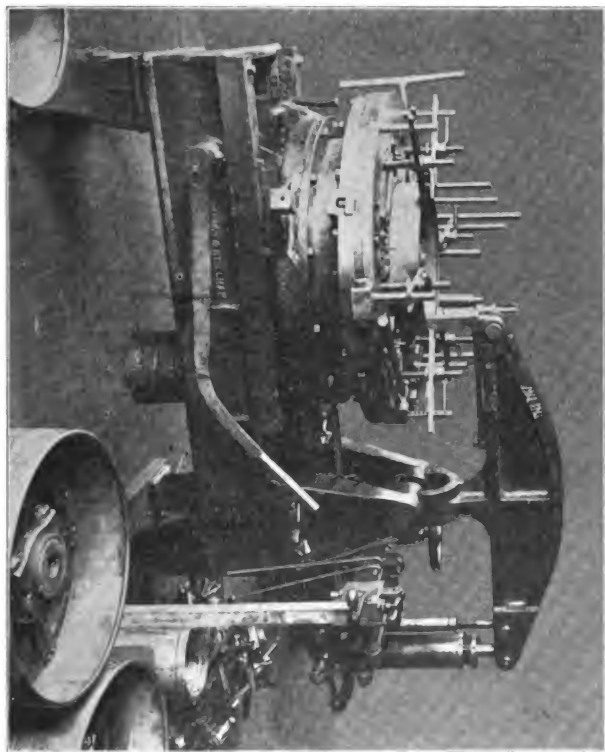
steel and forming them into U-shaped sections, the edges having been cut to fit around the half hub. A pair of these clamps are bolted together around the hub portion of the spider, thus holding the pulley firmly to the shaft.

During the process of manufacturing, the half rings, after being formed in the dies, are passed through bending rolls one



or more times until a perfectly formed semi-circular rim is produced without strain. The parts constituting the hub and spokes are annealed, whereby all strains are removed from these sections.

Hydraulic machine for riveting spider-arms to rims.

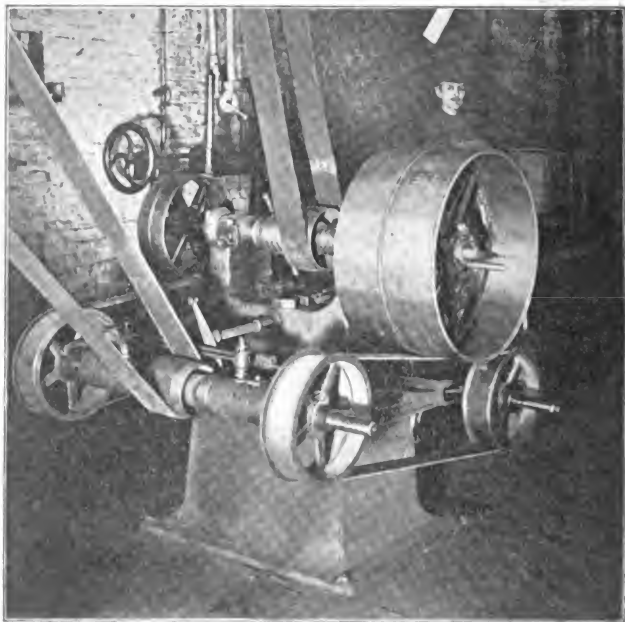


The different parts being cut from the plates with punching dies are so nearly alike that they are interchangeable, and when the pulleys are assembled they are nearly balanced, more so than cast-iron pulleys usually are.

The pulleys are very light, so much so that one man can

put a 36-inch pulley upon a shaft and secure it thereto without assistance.

The American Pulley Company, owners of the patents, are now manufacturing pulleys from 6 to 24 inches in diameter, with faces from 2 to 12 inches in width, and they are now building machinery to manufacture all desirable sizes up to 60



Polishing machine.

inches in diameter. The hubs of all sizes of pulleys are made to fit the larger sizes of shafting, for which they are likely to be used, and bushings are furnished to reduce the bore to fit the smaller sizes.

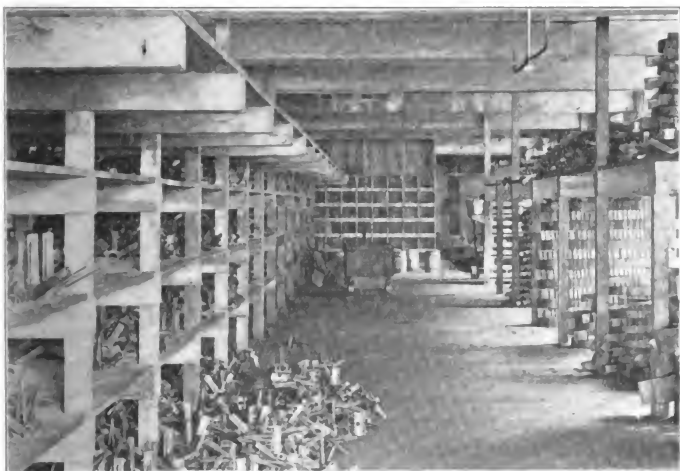
Keys in the shafting or set screws in the hub are not usually employed with these pulleys, but are furnished when required.

The pulleys are usually secured to the shafting with the clamping device above described.

The pulley is the lightest one known, its weight being only one-third of cast-iron pulleys of corresponding sizes, which the new construction notably surpasses in strength.

The price at which the new pulleys are sold is comparatively low, being lower than cast-iron pulleys of corresponding sizes.

The committee charged with this investigation believes that Mr. Corscaden has brought the manufacturing of belt pulleys to a degree of efficiency never before reached, and that



Stockroom, showing parts of pulley ready for assembling.

the manufacturers using pulleys will be greatly benefited by his inventions, and that the energy displayed by the inventor in producing so good an article at a low cost and in quantities that will enable the manufacturers and dealers to carry in stock all desirable sizes of pulleys is most commendable, and the committee believes that Mr. Corscaden merits the highest award of the Franklin Institute for his ingenuity in designing and perfecting this pulley and the machinery and system for manufacturing the same.

In view of the facts above set forth, the Franklin Institute awards to Thomas Corscaden, of Philadelphia, the Elliott Cresson Medal.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, September 1, 1897.\*

Countersigned, JOHN BIRKINBINE, *President.*

JAMES CHRISTIE, WM. H. WAHL, *Secretary.*

*Chairman of the*

*Committee on Science and the Arts.*

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## THE SPECIFIC HEAT OF ANHYDROUS LIQUID AMMONIA.

BY

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AND

WILLIAM D. ENNIS, M.E., LONG BRANCH, N. J.

*Concluded from Vol. cxlv, p. 198.*

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### METHODS.

(1) *Preliminary Operations.* In previous determinations the ammonia had always been heated in the vapor of some volatile liquid. We concluded that, for uniformity, simplicity, and cheapness, it was preferable to surround it with melting ice, taking the proper precautions to prevent moisture from condensing on the surface of the holder. The method employed is believed to be somewhat original, but to involve no new principle.

Some doubt being expressed as to the purity of the samples of ammonia furnished, a small amount was drawn off into a beaker and allowed to stand in the open air. It appeared to be perfectly clear, and, upon complete evaporation, left only a trace of an oily residue, due to the process of manufacture. A distilling apparatus was then arranged, as shown in *Fig. 5*. The pipe connections were coated with a paste composed of

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\* For the use of the illustrations in this report the *Journal* is indebted to the *Iron Age*.

glycerine and litharge, which gave almost perfect security from leakage. In a short time two or three pounds of ammonia were condensed over from the stock drum, and a sample of the distilled liquid was found to present exactly the same appearance as the commercial. Upon the surface of both, specks of what appeared to be floating oil were seen. This impurity was contained in quantities too small to affect the result of the tests as given; and, as manufactured ammonia always contains it, the conditions of actual practice were more nearly realized than they would have been with C. P. ammonia.

The following standard test directions were followed in the tests for purity:

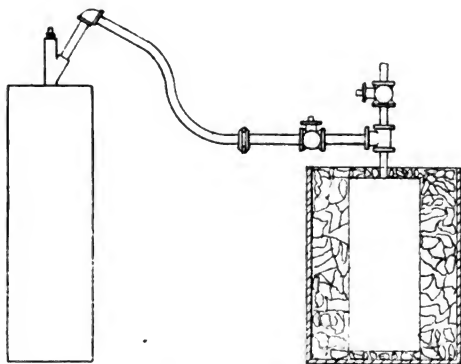


FIG. 5.—Distilling apparatus.

*Anhydrous Ammonia Test Directions.*—"To make the test, proceed as follows: Screw a short iron pipe, say 8 or 10 inches long, into the valve (it is best to loosen the valve stem after screwing on the pipe and to blow off a little of the gas so as to remove any dust or dirt that may have collected in the opening of the valve), slip the neck of the bottle over the pipe so that the latter projects into the bottle, open the valve a very little until the bottle is filled about one-fourth or one-half full, then remove the bottle, put on the cork with bent tube, and let the ammonia evaporate. As the evaporation may cool the liquid to such an extent as to cause it to freeze, it is well to hold

the bottom of the bottle in a bucket of water, moving it around to prevent ice from forming.

"After the ammonia has evaporated and the outside of the bottle has been wiped off dry, there should be no moisture left on the inside of the bottle. Of course, it is necessary that the inside of the bottle should be entirely dry and clean before drawing each sample. It is also necessary that the iron pipe should be entirely dry and clean before drawing each sample, as, after drawing samples, the evaporation of the ammonia cools the iron to such an extent that moisture from the air is condensed on the inside of the pipe.

"Caution should be used in drawing samples, as accident may occur by the ammonia spurting on the hands, in the face, or in the eyes of the operator."

*Filling the Holder.*—The ammonia holder was placed in a split block in a vise, and the cylinder containing the liquid was propped so that the discharge-pipe was directly over the holder. Due precautions being taken against moisture, and the other end of the cylinder being elevated, the valve was opened slightly to allow a few drops of mingled liquid and vapor to flow through. Then the valve was opened wide, the holder being now cooled to a low temperature, and the latter was filled with the liquid. The operator's hands were protected with gloves.

Some of the liquid was also allowed to run into an evaporating dish, in which the cap and pin were placed. The thread on the holder was then quickly smeared with the litharge and glycerine paste. The contents were allowed to evaporate until sufficient room was left for vapor and for the expansion of the liquid, when the cap was screwed down tightly. The pin was then driven in. By this arrangement it was possible to tighten the cap against the pressure within, and the final closing was effected instantaneously before the pressure had a chance to rise. The holder was placed at once in water at a temperature of about 36° C. as a test of its strength. Upon taking it from the water, after a reasonable time had elapsed, no leak was perceptible. Hydrochloric acid was used, as well as the ocular and olfactory tests, but it was not until two weigh-



ings had been made at an interval of sixteen hours that vapor was found to be escaping. Having made some previous attempts, we concluded that it was impracticable to make the holder perfectly tight, and determined to proceed with our test, the amount of loss being so small as to be almost imperceptible, and what loss there was giving the additional advantage of introducing a variable weight of ammonia into the thermodynamic equation.

(2) *Standardizing the Apparatus.*—The C. G. S. system was used throughout. Three Centigrade thermometers were employed, No. 1 being used for determining temperatures of the air only and graduated to half degrees, Nos. 2 and 3 being used in determining the initial temperature of the ammonia and the initial and final temperatures of the water, and graduated to tenths of degrees. They were standardized as follows:

Barometer, 761.35 mm., temperature . . . . .	18°·3 C.
To reduce to grams at Paris divide by . . . . .	1.00075.
Corrected barometer . . . . .	759.57 mm.
Thermometer (1) read . . . . .	100°·2 C. at boiling.
Corrected reading (protruding stem) . . . . .	100°·38 C.
Temperature of boiling for 759.57 mm. . . . .	99°·99 C.
<hr/>	
Difference . . . . .	0°·39 C.
In melting ice, reading was . . . . .	0°·31 C.
Average correction for (1) is then . . . . .	—0°·35 C.

In the same manner the correction for (2) was found to be + 0°·05 C., and for (3), — 0°·37 C.

The calculation for the approximate size of calorimeter required was as follows:

Contents of holder, about one cubic inch.	
Lowest temperature of holder . . . . .	32° F.
Highest " " " . . . . .	72° F.
Range " " " . . . . .	40° F.

If range in calorimeter is to be 5° F., the volume of water required is  $40/5 = 8$  cubic inches.

The calorimeter was made of 2 inches diameter, 3 inches high. This gave a range even better than that assumed.

The English system was used in this calculation to avoid transformation for the workman.

(3) *Determinations.*—A silk thread was drawn through the

fine tube *C*, *Fig. 3*, the holder was attached to it and raised into the chamber *A*, when the cover *F* was clamped on the bottom. The thermometer was introduced into the tube *D*, care being taken to make the mercury column cross the axis of the sight-tubes *E E*. The tank was then filled with ice, which was replenished as rapidly as it melted. The cathetometer was adjusted so as to have its axis vertical, and the telescope was levelled and focussed on the mercury column, a light being placed on the other side of the sight-tube to illuminate the thermometer divisions. The time required for cooling was about four hours. There was no difference found between the second and third determinations, hence it was concluded that four hours were sufficient to bring the temperature of the ammonia down to that of the air chamber or within a fraction of a degree above  $0^{\circ}$  C. The actual times of cooling were, however, from five to nearly twenty hours.

When the desired period of time had elapsed water was introduced into the calorimeter, the rate of evaporation determined, and the temperature of the air and of the water read. The temperature of the air chamber was read through the telescope and estimated to the hundredth of a degree with the high magnifying power of the lens. The mercury was observed not to rise in the tube uniformly but to advance by short jumps, which would indicate the impossibility of getting more accurate readings. The influence of radiation between the water and the air was taken into account, as indicated in the calculation given.

Then, by a quick manipulation, the bottom plate of the cooler was removed and the holder lowered into the calorimeter. The time of beginning the experiment was noted. It required about two minutes to bring the calorimeter down to its lowest temperature. The holder was afterward dried and weighed.

No. of test.	Time of cooling, hours.	Evaporation of water per minute, grams.	Average weight during test, grams.	Time of beginning test.	Temperature of air, C.	Initial temperature of water, C.	Immersion of thermometer.	Final temperature of water, C.	Immersion of thermometer.	Initial temperature of holder, C.	Time of ending test.	Temperature of water 5 minutes after test, C.	Degrees rise per minute, C.	Immersion of thermometer, C.	Weight of holder and contents, grams.
to det. therm. equiv.															
1	6	001	126.469	1:49:45	22° 3	24° 07	-0° 8	18° 52	1° 5	0.31	1:53:45	18° 76	0° 048	-1° 4	103.235
2	4	006	116.354	4:16:45	23° 0	23° 70	-2° 8	20° 02	-0° 3	0.30	4:17:45	20° 27	0° 050	-2° 5	92.971
3	3	006	114.201	2:53:15	22° 7	24° 60	-2° 5	20° 03	-0° 4	0.71	2:55	20° 32	0° 058	-2° 8	92.936
4	16	003	118.247	8:22	20° 1	20° 21	-2° 5	16° 52	-0° 1	0.40	8:25	16° 70	0° 030	-2° 8	92.873
5	5	002	119.761	12:33:40	23° 5	19° 75	-2° 5	17° 57	0°	0.51	12:35:15	17° 77	0° 040	-2° 5	92.794
6	18	008	121.482	4:22	24° 2	20° 39	-1° 4	21° 05	1°	0.34	4:24	22° 15	0° 041	-1° 5	92.793
7	5	002	120.091	11:27:30	23° 4	20° 66	-1° 3	18° 61	1°	0.05	11:29:30	19° 08	0° 004	-1° 5	92.791
8	18	002	125.816	3:25	24° 5	22° 37	-1° 1	18° 49	1° 5	0.92	3:26:15	19° 25	0° 152	-1° 0	92.788
9	5	001	127.554	11:51:30	22° 7	21° 89	-0° 8	18° 16	1° 7	0.62	11:52:45	18° 36	0° 040	-1° 0	92.787
10	18	001	127.319	4:13:30	22° 3	21° 68	-1° 3	19° 08	1° 5	0.71	4:15:15	19° 50	0° 064	-1° 4	92.785

DATA.

Nine experiments were made. Ludeking and Starr made six, which we concluded was too small a number. Von Strombeck made eight. The difficulty of determining the specific heat lies largely in the fact that it is a "difference quantity," and hence a large number of tests is essential.

The entire data for the whole series of tests are given on the preceding page. The following factors remained constant throughout:

Weight of copper calorimeter . . . . .	38.821	grams.
Water equivalent of " . . . . .	3.6905	"
Weight of steel holder . . . . .	81.001	"
Water equivalent of holder . . . . .	9.4366	"
Weight of lead and litharge* . . . . .	2.521	"
Water equivalent of same . . . . .	0.07916	"
Weight of holder filled with water . . . . .	103.235	"
Weight of water in holder . . . . .	19.713	"
Weight of water that would be contained at 4° C. . . . .	19.757	"
Equivalent quantity of ammonia that would be contained at 4° C. . . . .	12.463	"

*Note.*—The specific gravity of the ammonia was calculated from D'Andreff's formula,†

$$d = .6364 - .0014 t^{\circ},$$

where  $d$  = density,  $t$  = temperature Centigrade.

All temperatures given in the table are corrected for thermometric variation, but not for the protruding stem of the thermometer.

The ammonia tables given in Professor Wood's *Thermodynamics* were used in the calculations.

After the completion of the tests the ammonia was emptied from the holder and the latter filled with water, care being taken to screw down the cap to precisely the same position. The water was heated until slightly above the temperature of the room, the pin being removed, so that there was no danger of explosion when driven in. By weighing the holder under these conditions its cubic contents were ascertained. A determination of the specific heat of water was then made with a view to checking the accuracy of the methods used. The result obtained was .997, an error of less than one-third of one per cent.

\* The quantity of paste used was so small that the error in including it with the lead is inappreciable.

† Trans. A. S. M. E., 10, 641.

The water equivalent of the portion of the thermometer immersed in the calorimeter was found in the following two ways:

(1) *Method*.—Water was introduced into the holder and an experiment made with the water value of the immersed part of the thermometer as the unknown quantity. The following were the observed data:

Initial temperature calorimeter water . . . . .	24°·07 C.
Temperature air . . . . .	22°·30 C.
Immersion of thermometer . . . . .	0°·80 C.
Final temperature calorimeter water . . . . .	18°·52 C.
Immersion of thermometer . . . . .	1°·50 C.
Weight of water in holder . . . . .	19·713 grams.
Water equivalent of holder . . . . .	9·516 "
Weight of water in calorimeter . . . . .	87·648 "
Water equivalent of calorimeter . . . . .	3·691 "
Rise of temperature in calorimeter in five minutes .	0°·24 C.
Time required for experiment . . . . .	3·25 minutes.
Initial temperature holder . . . . .	0°·31 C.
Water equivalent of thermometer . . . . .	X.

Calculations as follows:

Corrected temperatures by formula

$$\frac{n(T-t)}{6480} = \frac{24^{\circ}\cdot87(24^{\circ}\cdot07 - 22^{\circ}\cdot30)}{6480} = 0\cdot00679$$

$$24^{\circ}\cdot07 + 0\cdot007 = 24^{\circ}\cdot007 = \text{corr. in. temp. of cal.}$$

$$\frac{17^{\circ}\cdot02(18^{\circ}\cdot52 - 22^{\circ}\cdot30)}{6480} = -0\cdot010$$

$$18^{\circ}\cdot52 - 0\cdot010 = 18^{\circ}\cdot51 = \text{corr. fin. temp. of cal.}$$

Radiation factor per min., =  $0\cdot24 \div 5 = 0\cdot048$  C. (In this case, the cooling at first was so rapid that the water was below the temperature of the air before any interchange of heat took place.)

$$\text{Total radiation factor} = 0\cdot048 \times 3\cdot25 = 0\cdot156 \text{ C.}$$

$$\text{Range in cal.} = 24^{\circ}\cdot077 - 18^{\circ}\cdot51 = 5^{\circ}\cdot57 \text{ C.}$$

$$\text{Range if no radiation, } 18^{\circ}\cdot20 - 0\cdot156 = 18^{\circ}\cdot044 \text{ C.}$$

Equation:

$$(9\cdot516 + 19\cdot713) 18^{\circ}\cdot044 = (3\cdot691 + 87\cdot648) 5^{\circ}\cdot716 + 5^{\circ}\cdot716 X.$$

From which  $X = .98$ , which is the water equivalent of the thermometer immersed to  $1^{\circ}.5$  C., at a temperature of  $24^{\circ}.08$  C.—an average value.

(2) *Method.\**—Method of finding the water equivalent by weighing:

Suspend the thermometer, *Fig. 6*, by two threads, one at *A*, the end of the stem, and the other at *B*, where the stem joins the bulb. Hang the end *A* to one arm of a balance, and hang the other end from any convenient support.

Cool the bulb so that the mercury stands at *D*, some place near *B*, and weigh the end *A*. Then warm the bulb, and when the mercury has advanced some distance as *D C*, weigh the end *A* again.

Knowing the difference of weight of *A* and the amount of expanded mercury, we have sufficient data to calculate the weight of mercury in the thermometer.



FIG. 6.

In the following let

$A B$  be the length of the stem;

$D A$  the original distance from the end of the mercury to *A*.

$C A$  the final distance from the end of the mercury to *A*.

$D A - C A = D C$  the distance the mercury has advanced.

$w'$  the initial weight at *A*.

$w''$  the final weight at *A*.

$w'' - w' = w$ , the increase in weight at *A*, due to the expansion of the mercury.

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\* This method of finding the water equivalent of a thermometer is due to the late Dr. A. M. Mayer.

Then the total increase in weight of the stem due to the expansion of the mercury equals

$$\left( \frac{AB}{\frac{CD}{2} + DB} \right) w$$

and the total weight of mercury in the thermometer is

$$\left( \frac{AB}{\frac{CD}{2} + DB} \right) w \div (R \times N) \quad (a)$$

where  $R$  is the co-efficient of cubical expansion of mercury for  $1^\circ \text{C.}$ , and  $N$  is the number of degrees between  $D$  and  $C$ .

For the thermometer used,

$$AB = 35.3 \text{ cm.}$$

$$AD = 26.4 \text{ cm.}$$

$$AD - AC = CD = 13.0 \text{ cm.}$$

$$w' = 14.588 \text{ grams.}$$

$$w'' - w' = w = .013 \text{ grams.}$$

$$R = .0001818$$

$$R \times N = .0037269$$

$$AC = 13.4 \text{ cm.}$$

$$AB - AD = DB = 8.9 \text{ cm.}$$

$$w'' = 14.601 \text{ grams.}$$

$$N = 20.5 \text{ C.}$$

$$\text{and (a) becomes}$$

$$\left( \frac{35.3}{15.4} \right) .013 \div .0037269 = 7.9 \text{ grams of mercury.}$$

Total weight of thermometer = 35.28 grams.  $35.28 - 7.9 = 27.38$  grams of glass.

Diameter of tube = .62 cm.

Then volume of tube

$$= \frac{\pi}{4} (.62)^2 \times 35.3 = 10.67 \text{ cm.}$$

$10.67 \times 2.5 = 26.67$  grams of glass in stem or from  $A$  to  $B$ , where 2.5 is the specific gravity of the glass.

$27.38 - 26.67 = .71$  grams of glass in the bulb.

$26.67 + 35.5 = .755 = \text{wt. of glass per cm.}$

If 4.4 cm. of the stem be immersed, then the total weight of glass immersed is

$$(4.4 \times .755) + .71 = 4.03 \text{ grams.}$$

Specific heat of glass = .194.

Specific heat of mercury = .0333.

Therefore the water value of the portion of the thermometer immersed will be

$$(4.03 \times .194) + (7.9 \times .0333) = 1.04.$$

The other result being .98, we assumed 1.00 as the water equivalent of the thermometer, which was always immersed to about the same depth, the bulb being in every case completely immersed in the water. The error could not be reduced to a much smaller amount than that given by this method, except by an extended series of tests, and, as the figure is not very important in the equation, the value 1.00 was considered sufficiently accurate.

The complete calculations for a single experiment are given below.

#### TEST NO. 9.

Weight of water and calorimeter at 3.57 P.M. . . . .	127.336 grams.
" " " " " 4.07 " . . . . .	127.326 "
Evaporation in ten minutes . . . . .	.010 "
" " " " " one minute . . . . .	.001 "
Time at middle of duration of test . . . . .	4.14:23 P.M.
Evaporation for 4.14:23 — 3.57 = 17.27 min. . . . .	.017 gram.
Weight of water + calorimeter during test . . . . .	127.319 grams.
Weight of calorimeter . . . . .	38.821 "
Weight of water . . . . .	88.498 "
Water equivalent of calorimeter . . . . .	3.691 "
Water equivalent of thermometer . . . . .	1.000 "
Total water value of calorimeter and contents . . . . .	93.189 "
Weight of ammonia holder and contents . . . . .	92.785 "
Weight of ammonia alone . . . . .	9.263 "
Water equivalent of steel part of holder . . . . .	9.437 "
" " " " " lead part of holder* . . . . .	.079 "
" " " " " all metal of " . . . . .	9.516 "
Volume of liquid ammonia in holder,	
9.263 ÷ .6345 = 14.578 c.c. . . . .	14.578 c.c.
Total volume of holder . . . . .	19.757 "
Volume of vapor space at beginning of experiment,†	5.179 "
" " " " " same at end (found in same way) . . . . .	4.564 "
One c.c. at 0.71 C. weighs . . . . .	.00361 grams.
" " 19.08 C. " . . . . .	.00663 "
Weight of vapor in holder at 0.71 C.,	
.00361 × 5.179 = .01870 . . . . .	.01870 "

\*Litharge paste being included as lead.

† Neglecting expansion of liquid.



Weight of same at 19°·08 C. (found same way) . . .	·03026 grams.
Difference in weight of vapor . . . . .	·01156 "
Heat used in vaporization, $295\cdot4^* \times \cdot01156$ . . . . .	3·414 calories.
Initial temperature of water . . . . .	22°·61 C.
Final " " . . . . .	19°·08 C.
Initial " of holder . . . . .	0°·71 C.
Temperature of air . . . . .	23°·30 C.
Rise in temperature of water in five minutes after test . . .	0°·42 C.
Corrected initial temperature of water† . . . . .	22°·61 C.

$$22^{\circ}\cdot61 + \frac{23^{\circ}\cdot91(22^{\circ}\cdot61 - 23^{\circ}\cdot30)}{6480} = 22^{\circ}\cdot61$$

Corrected final temperature of water . . . . .	19°·07 C.
Duration of test . . . . .	1·75 min.
Absorption of heat from air during cooling in the calorimeter, $0\cdot42 \div 5 \times 1\cdot75$ . . . . .	0°·147 C.

Range of temperature in calorimeter if there had been no decrease due to the warming influence of the air,  
 $22^{\circ}\cdot61 - 19^{\circ}\cdot07 + 0\cdot147$  . . . . .  $3^{\circ}\cdot687$  C.

Range in holder under same conditions,  
 $19^{\circ}\cdot07 - 0^{\circ}\cdot71 - 0\cdot147$  . . . . .  $18^{\circ}\cdot213$  C.

The thermodynamic equation is, then,  
 $(93\cdot189)(3\cdot687) = (9\cdot516 + 9\cdot263x)18\cdot213 + 3\cdot414,$

whence  $x$ , the specific heat of the liquid ammonia,  
 $= \cdot989.$

The results for the nine experiments were as follows:

(1) 1·056	(2) 1·037	(3) 1·002
(4) 1·040	(5) 1·031	(6) 1·020
(7) ·983	(8) 1·028	(9) 0·989

The average result is 1·0206.

Certain known facts indicate the probability of the above result.

It practically agrees with the values deduced by Prof. Wood, his formula giving, for the conditions under which the experiment was made, ·98.

Ledoux's formula gives for a temperature of 10° C., which was about the average during our tests, the value 1·04.

The value 1·00 has been largely used by engineers, and has not appeared to be greatly in error.

\* Average heat of vaporization between initial and final temperatures of holder.  
 Formula,

$$T + \frac{n(T-t)}{6480}, \text{ where } \begin{cases} n = \text{number of degrees protrusion.} \\ T = \text{temperature of water.} \\ t = \text{temperature of air.} \end{cases}$$

An average of all previous determinations gives (see page 194) 1.01.

The specific heat of superheated ammonia is .506 as against .48 for steam gas, an increase of 5 per cent. Our value for the liquid is 2 per cent. greater than for that of water.

The determination was made, as will be seen from the data, when the temperature of the ammonia ranged from about 0° C. to 20° C. This is nearer the temperatures of actual practice than Von Strombeck's of 60° C., or even of Ludeking's and Starr's of 40° C. The last-named investigators made three additional experiments with melting ice as a cooling medium, but so little is said of them, and that little is so indefinite that it is impossible to judge of the work intelligently.

We should suppose that a determination made when the iron shell was cooled in direct contact with the ice would be very approximate indeed.

The specific heat is undoubtedly variable, like that of water. In ordinary commercial calculations, the value for water is considered to be unity for all temperatures; and for such purposes that of ammonia may also be taken as constant.

The following table shows roughly that the value should increase with the temperature:

Authority.	Temperature at which exp. was made.	Specific heat.	Specific heat by theory.				
			Ledoux.	Zeuner.	*Wood.	†Wood.	‡Wood.
Von Strombeck	45° C.	1.229	1.17	1.38		1.17	.96
Ludeking and Starr	40° C.	.886	1.14	1.34		1.17	.97
Elleau and Ennis	10° C.	1.021	1.04	1.10	.98	1.14	1.04

\* See formula given above, page 193.

† *Trans. A. S. M. E.*, 12, 136.  $C = 1.12136 + .000438 T$ .

‡ *Trans. A. S. M. E.*, 10, 645.  $C = 1.096 - .0012 T$ .

Prof. Wood's first formula makes the variation downward in one part of the scale and upward in another part, which corresponds with Prof. Rowland's law of variation for water.

To state an experimental value obtained by these methods

to five decimal places, even as an average, seems to be far beyond any accuracy which the data will warrant.

The "greatest possible error" is large, because of some of the insufficiently-determined constants. When the latent heat shall be conclusively and accurately established, a revision of these calculations might make a very small difference in the result.

If we assume all errors to be in the same direction, and as large as possible, as follows:

Error in weighing . . . . .	.001 grams.
Error in reading temperatures . . . . .	.0°·01 C.
Error in tabular heat of vaporization . . . . .	.5 per cent.

we have, for the variation of result, 6 per cent. The maximum probable error is then about 3 per cent. The average of nine determinations is then reliable within one-third of one per cent.

From the evidences given in the data and the above remarks, our conclusion is that the experimental specific heat of anhydrous liquid ammonia is 1·02 at 10° C., a practical confirmation of the theories of Zeuner, Ledoux, and Wood. For those who prefer to use the variable value, Ledoux' formula, with the first constant reduced, is convenient:

$$.r = .9834 + .003658 t^{\circ} \text{ C.}$$

# THE FRANKLIN INSTITUTE.

*Annual Meeting, Wednesday, January 19, 1898.*

## TESTS OF THE SYNCHRONOGRAPH ON THE TELEGRAPH LINES OF THE BRITISH GOVERNMENT.

### THE WHEATSTONE RECEIVER OPERATED BY THE ALTERNATING CURRENT IN TRANSMITTING INTELLIGENCE.

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*(Concluded from vol. cxlv, p. 178.)*

### EXPERIMENTS WITH THE ARTIFICIAL CABLE.

Opportunity was presented for preliminary tests of this method of transmitting signals over the artificial cable belonging to the British Post Office Department, and of making direct comparisons of the alternating-current method with the present Wheatstone system over the identical cable. These trials were made on August 21, 1897. This cable, which represents to within 1 per cent. the real cable such as is used from England to the continent, to Ireland, the Channel Islands, etc., is made in 60 sections of three knots each, making a total of 180 knots or 207.5 miles. Each section has  $K$  equal to 1 microfarad and  $R = 33$  ohms, making total  $K = 60$  microfarads and total  $R = 33 \times 60 = 1,980$  ohms, and total  $KR = 118,800$ . The cable is of the type in which the distributed capacity is obtained by condensers placed at regular intervals along its length.

Through this cable, with a voltage of 110, messages were sent at a frequency of 93.6 or 187.2 alternations per second, using the synchronograph and the chemical receiver. The next experiment was with the Wheatstone system transmitter

and receiver, using 100 volts constant potential, and a speed of 120 words per minute equivalent to 72 complete waves per second was reached by the post office officials. Since the speeds vary inversely as the squares of the lengths, a frequency of 93.6, for example, over the 180-knot cable, corresponds to 210.6 or 421.2 alternations per second over a cable of 120 knots in length.

The cables from England to the continent are not at present operated by the Wheatstone system, although by so doing the speed would undoubtedly be increased; but the Hughes system, by a present international agreement, is employed. By the Hughes system the messages are received printed ready to be delivered. The continental cables are operated at about 100 words per minute by this system.

#### EXPERIMENTS SUNDAY, AUGUST 22, 1897.

With the experience already gained and the constants of the Wheatstone receiver measured a wider range of experiments was planned for this date, which were to include tests over each line for speed as follows:

- (1) Wheatstone transmitter and receiver.
- (2) Synchronograph and Wheatstone receiver.
- (3) Synchronograph and chemical receiver.

Two other lines were made up for this date, which, being used both with and without earth, were equivalent to four separate lines as before, making eight lines tested in all with a total *KR* for the longest line equal to 261,215. The constants for the first line used on this date are given in the following table:

SECTION.		MILEAGE.		TOTAL R.	K.		Total K.	KR.
From	To	Open.	Covered.	B. A. Units.	Open.	Covered.		
London	York	197'63	16'87	1738	2'96	4'55	7'51	13052
York	Leeds	28'25	2'50	500	'44	'67	1'11	555
Leeds	London	198'11	2'83	545	2'57	'76	3'33	1815
		423'99	22'20	2783	5'97	5'98	11'95	33457

This line had a measured resistance by the Wheatstone bridge just prior to the tests of 2,799 ohms.

From long experience in the British service the basis which is there used to calculate the number of words per minute in terms of complete cycles of current by the Wheatstone system is 36 complete cycles = one word, or  $\cdot 6$  of a complete cycle of current per second equals one word per minute. This basis has therefore been used throughout in calculating the comparative speeds, using the synchronograph with the Wheatstone receiver, so that the comparative results given are independent of the length adopted for a dash or indeed of the particular code employed. The Wheatstone instruments were in all cases operated by operators of the telegraph department.

York line, with no earth, total  $KR = 8,314$ .

Synchronograph and Wheatstone receiver sent 666 words per minute, corresponding to 266.4 complete waves of current per second. The coils of the receiver were joined in parallel, giving an  $L = .875$  henry and no condensers were used. Voltage, 175. In this line, where the mechanical limit of the Wheatstone receiver is reached before the speed is limited by the total value of  $KR$  of the line, it is seen how the perfect regularity, equality and shape of the sine waves materially increased the upper limit of the Wheatstone receiver.

*Synchronograph and Chemical Receiver.*—With this combination the alternator was run higher than before, until a frequency of 723 was attained, or 1,446 single impulses per second or 86,760 per minute.

York line with earth—total  $KR = 33,257$ .

Wheatstone transmitter and receiver sent 360 words per minute with a voltage of 100. Synchronograph with Wheatstone receiver sent 540 words per minute, voltage 200. Receiver coils in parallel  $L = .875$  and condenser shunt across the coils of .725 microfarads. No limit was obtained in this experiment.

The longest line as yet tested, of 1,097 miles, was then made up with data as given in the table below:

SECTION.		MILEAGE.		R.	K.		Total K.	KR.
From	To	Open.	Covered.	B. A. Units.	Open.	Covered.		
London	Aberdeen	499'56	35'50	6020	7'79	9'58	17'37	104567
Aberdeen	Glasgow	147'19	3'86	1805	2'30	1'04	3'34	6029
Glasgow	London	402'72	8'74	1075	6'28	2'36	8'64	9288
		1049'47	48'10	8900	16'37	12'98	29'35	261215

*Route.*—London to Aberdeen *via* York and Edinburgh, and return to Glasgow and Leeds. A portion of the line north of Edinburgh was iron wire upon the same poles, going and returning.

Aberdeen line no earth total  $KR = 65,304$ .

Wheatstone transmitter and receiver sent over this line 185 words per minute, voltage 100.

Synchronograph and Wheatstone receiver sent over this line 540 words per minute, voltage 215, coils in parallel.

Synchronograph with chemical receiver sent at frequency of 723 or limit at which it was safe to run the alternator. This result was higher than expected from the approximate law indicated by the preceding trials, and a reason for this was sought. The line was broken at Aberdeen and records were still received. It was then restored at Aberdeen and broken at Glasgow, when as before no record was obtained. The cause of this was thought to be the inductive effect of that portion of the line beyond Glasgow, where the iron wires going and returning were unavoidably upon the same poles.

Aberdeen line with earth total  $KR = 261,215$ .

Wheatstone transmitter and receiver sent over this line 46 words per minute, voltage 100.

The synchronograph and Wheatstone receiver sent over this line 135 words per minute, voltage 85, coils in series  $L = 3.46$ , condenser of 5.75 microfarads shunted across coils.

The results of the foregoing experiments are given in tabulated form in *Fig. 15*.

## THE TRANSMISSION OF INTELLIGENCE IN GREAT BRITAIN.

One of the reasons for going to England was to become conversant with their method of conducting the telegraph and

No	Line	Miles	Total	Wheatstone	Spectrograph	Spectrograph	Generator	Wheatstone
		Open	Overall	Trans. received	Trans. received	Trans. received	res. No. of poles	Cells Cells Condenser series per 1 Wheatstone series 2
1	10A	521.00	22.20	448.19	22.98	2.91	134	
2	9	99	99	99	99	99	99	
3	8	99	99	99	99	99	99	
4	7	99	99	99	99	99	99	
5	6	99	99	99	99	99	99	
6	5	99	99	99	99	99	99	
7	4	99	99	99	99	99	99	
8	3	99	99	99	99	99	99	
9	2	99	99	99	99	99	99	
10	1	99	99	99	99	99	99	
11	0	99	99	99	99	99	99	
12	0	99	99	99	99	99	99	
13	0	99	99	99	99	99	99	
14	0	99	99	99	99	99	99	
15	0	99	99	99	99	99	99	
16	0	99	99	99	99	99	99	
17	0	99	99	99	99	99	99	
18	0	99	99	99	99	99	99	
19	0	99	99	99	99	99	99	
20	0	99	99	99	99	99	99	
21	0	99	99	99	99	99	99	

FIG. 15.

telephone business in conjunction with the general postal service in a country where these three departments are under the control of the Government.



In the prosecution of this as in the experiments themselves every facility was afforded by the Government officials.

It is recognized that to draw correct conclusions upon the general subject of the transmission of intelligence requires men of experience in dealing with such matters, who give the subject their attention for a considerable period. Some of the principal facts, however, seem to be so clearly defined in their relation to others that we feel warranted in making some observations thereon.

In the previous paper some data were given concerning the transmission of intelligence in the United States and in a similar manner will follow the data for Great Britain. This is shown in graphical form in *Fig. 16*, where seven curves are given, two for the total revenue and expenditure of the postal service in the United Kingdom and two for the revenue and expenditures of the telegraph department of the United Kingdom, one for the total number of letters only delivered in the United Kingdom, and one giving the number of telegrams forwarded from telegraph offices in the United Kingdom, and the seventh gives the per cent. of profit for the postal service.

The revenue from the postal service was about \$26,000,000 in 1872, and increased gradually until, in 1896, it had reached \$57,000,000. The expenses for this service in 1872 were about \$19,000,000, and increased gradually until, in 1896, they were about \$39,500,000. It is seen that the lines representing both revenue and expenditures are approximately straight, and that the revenue is invariably greater than the expenditure. In 1872 the per cent. of profit was about 37, and in 1890 it reached 55 per cent., while in 1896 it was 45.5 per cent. It should be understood that these amounts include the parcel post as well as the mail. The limit of weight which may be sent through the post office in this country is four pounds, but the parcel post of the British Government virtually does much business similar to that done by the express companies in the United States.

In 1896 the profit of the post and telegraph together was \$17,600,000. The Select Committee of the House of Commons in 1888 dwelt upon the necessity of working in the main upon

business principles with a view to a profit on the transactions of each year, and added that the high business character of the Post Office Department was in no small degree due to the fact that it had been administered in this spirit and from this point of view.

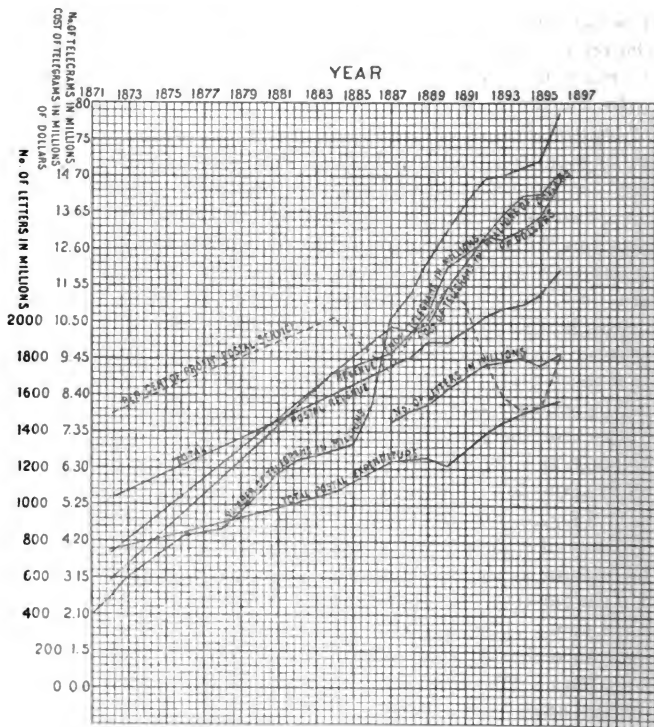


FIG. 16.

The number of letters delivered, not including post cards, was, in 1887, about 1,459,900,000, and in 1896 it was 1,834,200,000, the largest number.

Referring to the curves of telegraph revenue and expendi-

tures, it is seen that they each increase with approximate uniformity. In 1872 the revenue was about \$18,200,000 and the expenditure about \$14,500,000, while in 1896 the revenue was \$69,700,000 and expenditure \$70,500,000. These two curves nearly coincide and cross each other three times in twenty-five years, showing that the telegraph business is conducted on the whole to meet the expenses only and leave no profit. In some years the expenses are greater than the revenue, and the account shows a deficit. This has been the case for the last five years, but it has been gradually decreasing for three years, and in 1896 was only \$168,000.

The number of telegrams forwarded from telegraph offices in the United Kingdom in 1871 was 9,850,177 and in 1896 was 78,839,610, and the curve representing this shows a continual increase from year to year. In 1896 the ratio of the number of letters to telegrams was 18.5.

The charge for transmitting ordinary telegrams is a half-penny or one cent per word, including the address. The minimum charge is six pence, or about 12½ cents, and the same price for any distance. The telegraph is used to a much greater extent for transmitting news in England than in any other country; for instance, in 1896, 5,915,646 telegrams were transmitted at the press rates for newspapers, clubs, etc. The average weekly number of words contained in these telegrams was about 13,650,000. The average length of each telegram is therefore 120 words. The explanation of this is found in the reduced rate given to the press after 6 P.M., which is at present but six pence per hundred words. This press matter is handled almost entirely by the Wheatstone automatic system, where automatic telegraphy is more advanced than in any other country in the world. There are as many as 477 sets of Wheatstone instruments in use in Great Britain, and for press messages pneumatic perforators are used and a number of duplicate strips are prepared at once, and thus the same press news may be sent out on eight or nine different lines from London at the same time. Many of the lines, which are ordinarily operated by hand, are equipped with Wheatstone instruments. These are switched in whenever the traffic for the particular

line becomes too great for hand transmission. They are also much employed for temporary lines where an unusual volume is to be handled in a short time, such as in sending the enormous amount of racing and sporting news required.

The telephone service in England is not entirely under the control of the Government. The trunk lines are so controlled and operated, leaving to private companies the service in local districts. Some of these trunk lines were transferred to the Government on the 25th of March, 1896, by an agreement with the National Telephone Company.

In a country where the three great branches of intelligence transmission, the mail, the telegraph and the telephone, are under one management, special advantages to the people are obtained which are not given when these departments are separated. In England messages may be telephoned:

(1) For transmission over the postal telegraphs and delivery as telegrams.

(2) For delivery as express letters.

(3) For transmission and delivery as ordinary letters.

The telephone may also be used for obtaining the services of post office express messengers.

As indicating the increased demands for communication between England and the continent the following extract from the last report of the Postmaster-General on the post office is given: "The large increase in the number of telegrams passing over the Government cables to the continent, and in the number of conversations on the telephone circuits between London and Paris, has rendered it necessary to consider the advisability of improving the means of communication. With the cordial co-operation of the German post office, experiments were made with a view to improve the carrying capacity of the cables to Germany by the method of duplex working, which has been employed with success on some of the Anglo-French cables; but, owing to the greater length of the Anglo-German cables, the results obtained were not sufficiently successful to justify the adoption of the system for practical working. Arrangements have now been made for the laying of three additional cables to the continent, two to France and one to

Germany. These cables, each of which will contain four conductors, will afford a much-needed relief to the traffic; and it is expected that this new cable to Germany will prove suitable for duplex working."

#### CONCLUSION.

The results of the experiments described show that the use of an alternating electromotive force, which does not rise suddenly and fall off as abruptly as is the case with that of most transmitters, but which rises gradually from zero to a maximum and falls again to zero as gradually, is the best kind of wave for use on actual lines with distributed capacities.

The synchronograph, which employs this kind of an alternating electromotive force made and broken always at the neutral points, has thus far proved to be better than other transmitters for the transmission of electrical waves over a given line at any speed, slow as well as fast. An examination of the various methods employed for increasing the speed of working on submarine cables shows not only that in such methods the waves are made of equal lengths, but that an endeavor is made to compensate for the square tops of the electromotive force waves of the transmitter, which is usually accomplished by the aid of condensers or auxilliary electromotive forces judiciously arranged in shunt circuits. In other words, the attempt is made by these devices to approximate a sine wave as nearly as possible, while the remedies which can be applied by such means at best only approximate this form of wave. The synchronograph adopts a smooth wave, approaching practically the sine wave in form as its fundamental principle, and supplies a simple method of using the waves generated by an alternating dynamo.

The substitution of the synchronograph for the Wheatstone transmitter on the identical lines, using the same receiver in each instance, showed a speed of operation by the synchronograph about *three-fold* faster, provided the mechanical limit of the receiver was not already reached. The causes of this great increase of speed are differences in the waves which pass through the receiver; since the only way by which the

identical receiver can distinguish between transmitters is by differences in the actual waves received. The waves of current passing through the receiver, which control its operation, are not of the same shape as the electromotive force waves of the transmitter. The current waves with the Wheatstone transmitter, for instance, have more or less rounded tops, but they maintain the same frequency as the transmitter, and waves for a dash are longer than for a dot. The current waves received from the synchronograph are not true sine waves in the receiver, even though the electromotive force is truly harmonic, but the frequency is the same as that of the generator and the waves are of equal lengths. The current wave from an alternator may approximate a sine wave very closely if the electromotive force is harmonic, and in fact if there is no leakage on the line it will be truly harmonic; or under some circumstances it may still be harmonic, provided there is a correct relation between the leakage, resistance, inductance, and capacity. There are thus at least two causes which account for the slower speed with the Wheatstone transmitter, the fact that different frequencies or wave lengths are used in the transmitter and the departure from the sine form of wave.

Another cause for gain in speed by the synchronograph is the fact that higher voltage was permitted with it than with the Wheatstone transmitter, although it is difficult to estimate the precise amount of gain due to this. The reason for permitting different voltages lies in the construction of the instruments themselves; for with the synchronograph the contacts are made and broken at the zero points of the waves, and thus even when considerable capacity is present on the line, the amount of sparking is almost *nil* under circumstances when the Wheatstone transmitter would produce a powerful spark owing to the sudden application of the full voltage.

A fact which seems to point to the conclusion that the gain is due to the use of the sine form of wave rather than the adoption of uniform wave-lengths is the following: The experience with the Wheatstone system shows that the use of the condenser compensation before mentioned practically doubles the speed attainable on any given line by equalizing in some meas-

ure the line charges for the dash and the dot. This compensation is so perfect that the substitution of dots for dashes so as to make all waves of equal length and duration increases the attainable speed by about 5 per cent. only. The only difference remaining is the shape of the electromotive force wave when nothing but dots are used, so that it appears that the greater part of the gain is due to the use of the approximate sine wave.

Instead of comparing the speeds obtainable by the different transmitters on identical lines, another way of presenting the same facts is by the comparison of lengths and kinds of lines which permit the same speed with the two transmitters. This comparison is illustrated by the curves in *Fig. 17*, where the abscissæ represent miles of line and the ordinates represent words per minute on the basis of 36 complete waves per word as used in the English service. Seven curves are shown.

(1). The Wheatstone speed over iron wire of 400 pounds per mile;  $r = 14$  ohms, per mile;  $k = .01573$  microfarads per mile.

(2, 3 and 4) Wheatstone speeds over copper wires of 200 pounds per mile;  $r = 4.45$ ;  $k = .0150$ ; and of 400 pounds per mile;  $r = 2.225$ ;  $k = .0156$ ; and of 800 pounds per mile;  $r = 1.1125$ ;  $k = .0160$ .

(5, 6 and 7) Synchronograph and Wheatstone receiver speeds over the same copper wires as for curves 2, 3 and 4 respectively.

Referring to the general equation for Wheatstone speeds already given, which is

$$K R W = c = \text{a constant,}$$

if  $m =$  miles of line, then  $K = m k$ , and  $R = m r$  in which  $k$  and  $r$  are respectively capacity and resistance per mile.

Then

$$m^2 W = \frac{c}{k r} = c' = \text{a constant,}$$

which is the above equation when translated into miles instead of  $KR$ .

The equations of the above curves with numerical constants are:

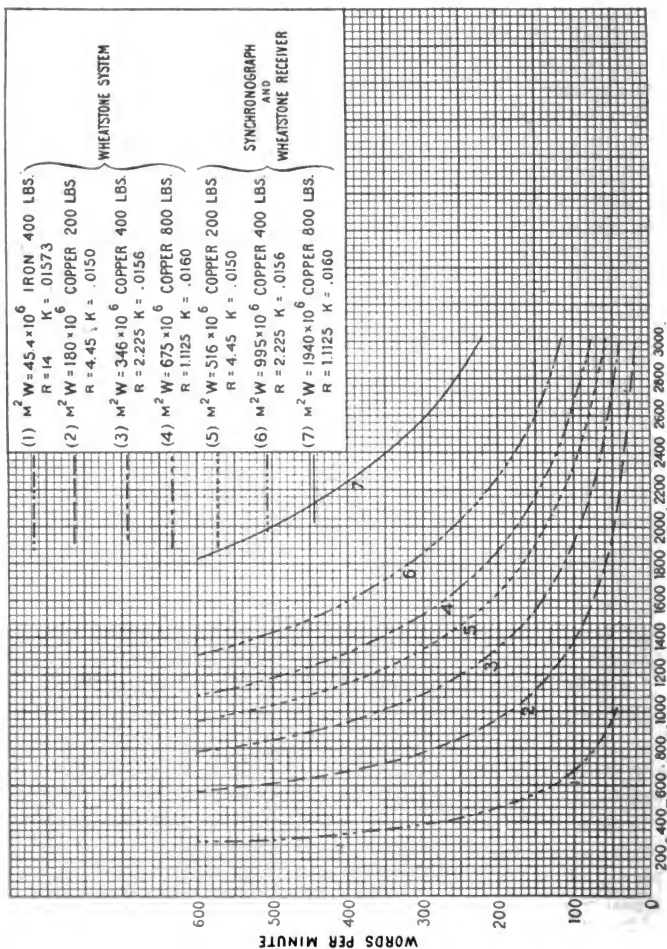


FIG. 17.



(1) $m^2 W = 45.4 \times 10^6$	} Wheatstone Transmitter and Receiver.
(2) $m^2 W = 180 \times 10^6$	
(3) $m^2 W = 346 \times 10^6$	
(4) $m^2 W = 675 \times 10^6$	
(5) $m^2 W = 516 \times 10^6$	} Synchronograph and Wheatstone Receiver.
(6) $m^2 W = 995 \times 10^6$	
(7) $m^2 W = 1940 \times 10^6$	

If  $c'$  is the constant for a given kind of wire with the Wheatstone system, and  $c''$  the constant for the synchronograph and Wheatstone receiver, we write  $m'^2 W' = c'$  and  $m''^2 W'' = c''$  as the equations for the two cases. If the same number of words per minute are to be sent then  $W' = W''$  and we have

$$\frac{m'}{m''} = \sqrt{\frac{c'}{c''}}$$

Since from experiment the ratio of  $c'$  to  $c''$  for any given line is approximately 3, we have

$$\frac{m'}{m''} = \sqrt{3} = 1.7.$$

That is, the synchronograph and Wheatstone receiver will operate on a line 1.7 times as long at the same speed as the Wheatstone system. The curves are limited as before at 600 words, which is the mechanical limit of the receiver. With copper wire 800 pounds per mile, the synchronograph can operate to the limit of the Wheatstone receiver any distance less than 1,800 miles.

The Wheatstone system using the same wire can operate to the same limit any distance less than 1,060 miles.

The synchronograph will operate the Wheatstone receiver at a speed of 215 words per minute on a line 3,000 miles long of 800 pounds copper. This is as high speed as is now used with Wheatstone in this country and no repeaters are required in the above case. The Wheatstone transmitter can send 75 words per minute on the same line.

The above calculation assumes the average line construction and climatic conditions in England.

Curve (1) exhibits the inferiority of iron as compared with copper wire; the curve shown is for 400 pounds iron wire.

The realization of an approximate sine wave of current at the receiver makes available at once the resonant method of augmenting the receiver current in a perfectly definite manner by the use of shunted condensers without changing the line current. In fact, knowing the inductance of the Wheatstone receiver, the proper condenser capacities were calculated for different speeds, and actual trials showed that the calculated capacities gave the best results.

With the Wheatstone waves such use of condensers is not followed, because resonance is not practicable with this kind of wave having different lengths and departing from the sine form. As before stated, the practice in England is to introduce into the line itself a large resistance around which the capacity is shunted and these adjusted by trial until the best results are obtained.

In view of these trials with the Wheatstone instruments it will be of interest to extend the experiments to other forms of instruments such as are now used or proposed for cable or automatic working. The gain in speed expected is less than with the Wheatstone system, since in long cables the transmitters used already employ waves of equal lengths.

It was interesting to observe whether a high frequency current, such as was used in these experiments, passing in a continuous loop of a thousand miles through a thickly-settled country, would cause any material disturbance in the telephone circuits of the region, but no such disturbances were reported, although orders were given for this to be noted.

It is believed that the Government control and operation of the telegraph would prove a great benefit to the people of the United States. The natural relation between this service and the general postal service requires that they should be under the same department for the most efficient and economical management.

## ELECTRICAL SECTION.

*Stated Meeting, October 26, 1897.*

### THE AMERICAN ELECTRIC METER.

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BY WM. DENNIS MARKS.

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The mechanism of this meter is so elementary in character that the accompanying illustration of a twenty-two-light meter requires but little explanation. The meter consists in the three-wire system of two solenoids and cores placed above a



Marks' electric meter.

self-starting pendulum actuated by the electric current. The pendulum, by means of a cam, raises a pawl on a ratchet wheel to a uniform height each stroke. The solenoids, by means of their cores, shift the angular position of a pendant arch attached to their axis so as to permit this pawl to drop along the ratchet wheel a number of teeth proportional to the cur-

rent passing through the meter. Thus, at each stroke of the pendulum, the load in ampères passing to the consumer is by means of the ratchet wheel and the dial register, measured and added up in ampère hours. That is all there is of the meter, save a pointer and scale showing through the glass the ampères passing. The interior mechanism is supported by a brass frame similar to that of a Yankee clock, and the case is cast-iron, thus acting as a magnetic shield, and preventing tampering with the meter by means of magnets on the outside.

#### CORRESPONDENCE.

### A CONTRIBUTION TO THE HISTORY OF THE ART OF PHOTOGRAPHING LIVING SUBJECTS IN MOTION, AND REPRODUCING THE NATURAL MOVEMENTS BY THE LANTERN.

*To the Editor of the Journal of the Franklin Institute :*

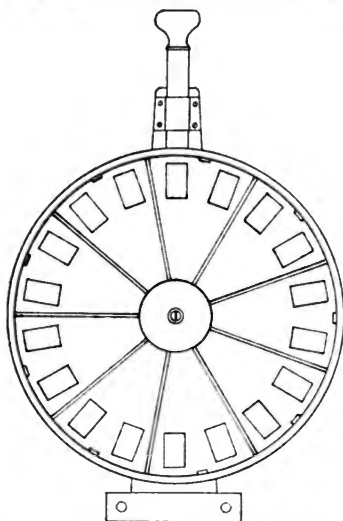
SIR :—Among the earliest public exhibitions of photographs taken from living subjects in motion projected by the lantern upon a screen, was that given at an entertainment held in the Academy of Music, in Philadelphia, on the evening of February 5, 1870,\* and a repetition of this exhibition was made before the Franklin Institute at its next following monthly meeting, on March 16th, by the writer.

The subjects exhibited embraced waltzing figures and acrobats, shown upon the screen in life-size, while the photographic images were only  $\frac{3}{4}$  inch in height. At that day flexible films were not known in photography, nor had the art of rapid succession picture-making been developed ; therefore, it was necessary to limit the views of subjects to those that could be taken by time exposures upon wet plates, which photos were afterwards reproduced as positives on very thin glass plates, in order that they might be light in weight. The waltzing figures, taken in six positions, corresponding to the six steps to complete a turn, were duplicated as often as necessary to fill the eighteen picture-spaces of the instrument which was used in connection with the lantern to project the images upon the screen.

\* The printed program of this event contains the following allusion to this feature of the entertainment : " THE PHASMATROPE. This is a recent scientific invention, designed to give to various objects and figures upon the screen the most \* \* life-like movements. The effects are similar to those produced in the familiar toy called the Zoetrope, where men are seen walking, running and performing various feats in the most perfect imitation of real life. This instrument is destined to become a most invaluable auxiliary to the appliances for illustration, and we have the pleasure of having the first opportunity of presenting its merits to our audience."

The piece of mechanism, then named the "Phasmatrope," shown by the illustration, consisted in a skeleton wheel having nine radial divisions, into which could be inserted the picture-holders, each of which consisted of a card upon which was mounted two of the photo positives, in such relative position that, as the wheel was intermittently revolved, each picture would register exactly with the position just left by the preceding one. The intermittent movement of the wheel was controlled by a ratchet and pawl mechanism operated by a reciprocating bar moved up and down by the hand. It will be apparent that the figures could be moved in rapid succession or quite slowly, or the wheel could be stopped at any point to complete an evolution.\*

In the exhibitions at the Academy of Music, above alluded to, the movement of the figures was made to correspond to the time of the waltz played



by an orchestra, and when the acrobat performers were shown a more rapid motion was given, and a full stop made when a somersault was completed. A shutter was then a necessary part of the apparatus to cut off the light rays during the time the pictures were changing places. This was accomplished by a vibrating shutter placed back of the picture wheel, that was operated by the same draw-bar that moved the wheel, only the shutter movement was so timed that it moved first and covered the picture before the latter moved, and completed the movement after the next picture was in place. This movement reduced to a great extent the flickering, and gave very natural and life-like representation of the moving figures.

HENRY R. HEYL.

PHILADELPHIA, February 1, 1898.

## NOTES AND COMMENTS.

## FELT MATS FOR RAILS.

Engineers and railway men are much interested in the results of tests now being made abroad with mats of felt, which are designed for laying under the rails of street railway lines for purposes of protection and sound deadening. The new mat, which is a German invention, was first exhibited at Leipsic last summer, and attracted considerable attention. It is described as made of strong wool, which is thoroughly impregnated with oils, then superficially coated with glue, which has been rendered insoluble by the addition of sodium bichromate and formaldehyde, and then very highly compressed to form plates from  $\frac{1}{3}$  inch to several inches in thickness and of various sizes. They are especially recommended for crossings and bridges, but are desirable for use all along the track, and it is claimed that they tend to prolong the life of the rail by lessening the wear on it. The surface of the mat is said to be so hard that a rail may be placed upon such a piece of matting without cutting into it. In addition the claim is made that by placing the mats under the bed plates-bearings between the joists and other such places in the engine rooms, the noises therein will be reduced to a minimum. The material is known by the name of iron felt. The main question is as to how long the mat will retain its elasticity. Another recommendation for the preparation is that it prevents rotting.—*Iron Age*.

## THE USE OF WATER METERS.

In Philadelphia, where some trouble is experienced in obtaining a proper supply of water, an attempt is being made to prevent the waste of water by the use of meters, to which some objection is being made. In commenting on this the *Ledger* makes the following observations: There should be no more opposition to water meters than there is to gas meters, and there would not be if the people were as well accustomed to the one as to the other. Their use is based on the same principle, and while there may be some difference in their application, since water is a necessity while gas is not, this is not enough to invalidate the principle. The use of water meters should be made compulsory and universal. It is true that water must be supplied to some persons who cannot pay for it, but it should be measured in every case, and the question of free delivery settled by itself. Measuring the water and paying for it are distinct questions, and need not be dealt with as inseparable. The use of meters is demanded as the only means to stop waste. At least half the water supplied to this city is wasted, and the waste not only costs as much money as the amount used, but it impairs the quality of the whole by withdrawing the water from the reservoirs before it has time to purify itself by subsidence. The introduction of meters would be the quickest way of affording relief in the water difficulty, and while it would not solve the problem it would help to preserve the health and comfort of the people while waiting for a pure-water system to be selected and installed.

## CHEMICAL EFFECT OF CATHODE RAYS.

Some experiments on the chemical effect produced by the impact cathode rays, made by Professors Momson and Skinner, are thus reported by London *Nature*: "Aluminum is rapidly evaporated from the cathode by an electric discharge in a highly exhausted vacuum tube in which air has been replaced by mercury vapor. The metal is condensed over the walls of the tube in the form of a bright mirror. An iron cathode gives a similar mirror in a mercury vapor discharge tube. When the aluminum coating is dissolved off the wall of the bulb by hydrochloric acid a gelatinous membrane remains, which gives the reactions of silica. When potassium vapor is used the glass opposite the aluminum cathode is roughened. In parts sheltered by screens from the discharge the glass is not attacked. In potassium vapor the aluminum cathode is not evaporated to any marked degree. Opposite the cathode, both in the mercury vapor and potassium vapor bulbs, a dark annular stain of the shape of the cathode is formed. This stain resists the action of strong hot hydrochloric acid, nitric acid, aqua regia, and potash solution. The action of hydrochloric acid removed it, apparently by dissolving the glass. The tests indicate carbon, but the quantity of the stain is too small to make certain. The stain is also formed on screens of mica, quartz and calcite. Monatomic gases appear to permit the evaporation of aluminum, as Professor Callendar has observed its evaporation in an argon vacuum tube."

## EFFLORESCENCE ON BRICKS AND SANDSTONES.

Efflorescences from the materials of our buildings are not ornamental, nor do they render the stones more durable, says *The Trade Journals Review*. About their causes and prevention we are pretty much at sea. Contractors are occasionally required to use stones free of nitre; nitrates have, in reality, little to do with the matter, and it is generally sulphates which cause the trouble. Some years ago, the Association of German Architects invited memoirs on the question. The general conclusion seemed to be that prevention was very difficult, and that time would bring its cure. A dissertation by Hans Günther, communicated in abstract in *Dingler's Polytechnisches Journal*, is not quite so resigned. Günther has evidently made a very careful and painstaking study of this uninteresting subject. The trouble may come from the clay, the water employed during the various stages, the ashes and pyrites of the coal, and from the mortar. The pyrites of the coal may certainly cause mischief, especially because modern practice is in favor of continuous ring kilns, which work with plenty of oxygen; while in the old periodical kilns the atmosphere was frequently reducing, so that little sulphuric acid was formed from the  $\text{SO}_2$ . The presence of sulphuric acid, we learn incidentally, favors the production of colored bricks, for it decomposes the yellow iron-lime silicate. But the author attaches more importance to the pyrites in the clay, and to chemical interaction between brick and mortar. He has very fully gone into this inquiry. He found *e. g.*, that certain bricks remained quite smooth when piled up, and became soon covered with efflorescences when used with a mortar which proved perfectly harmless to other bricks. Almost all clays contain pyrites, which, in the presence of magnesia, give rise to immediate efflorescences; in the presence of lime, only after decomposition

with the alkalies of the mortar. That the sulphates are the chief culprits he established beyond doubt. We may mention that the case is different in lavatories where ammonia is constantly liberated and slowly converted into nitrates. As a remedy, Günther suggests to admix baryta, as carbonate or chloride, which would bind the sulphuric acid. The sandstone blocks of the handsome new Town Hall at Hamburg suffer from this trouble.

A very intelligent discussion of this subject was published in this *Journal*, Vol. 106, p. 52, from the pen of Mr. Henry Pemberton. His paper related specially to the efflorescence on brick walls so generally seen in Philadelphia, and attributed the cause to the universal use, in Philadelphia, of dolomitic lime for the mortar used by our local masons. The action of the sulphurous gases from coal thrown out from innumerable chimneys, and carried down by rain water, in this author's opinion, explains the leaching out from the mortar of magnesium sulphate, which, after the drying out of the moisture, makes its appearance on the surface of the walls as a whitish coating. W.

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#### REPORTED DISCOVERY OF STRONTIUM.

The discovery of a large bed of strontium sulphate at Put-in-Bay, reported from Toledo, has awakened a considerable amount of interest among the manufacturers of fireworks, as it is thought likely that it will result in a considerable reduction in the price of all fireworks in which strontium nitrate or strontium carbonate is used. One large manufacturer of fireworks in New York, who makes use of about 150 tons of strontium nitrate in a year and imports the whole of it from Europe, states that it costs his firm now about 7¼ cents a pound. If the strontium should be found in large quantities, it would have the effect of lowering the cost of certain classes of fireworks, that is, all those that use a red or crimson light. At present the supply comes chiefly from Germany, and the American manufacturer has to pay a high price for it.—*Scientific American*.

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#### RECENT IMPROVEMENTS IN ARMOR PLATE.

Some mention has been made lately in foreign papers of a new process for making armor plate, which is said to produce a harder and better plate than the nickel-steel treated by the Harvey process, which has heretofore given the best results. The French Government has bought the right to use this process from the inventor, but the details have been carefully kept secret. It is also known that Krupp, the great German steel-maker, has a new process, which is either the same or a very similar one to the French. Enough is known of the process to say that it requires the use, in making the steel, of some of the rare metals, molybdenum, uranium and vanadium, which take place of nickel in the alloy resulting. We are informed by a correspondent, who has made many researches into the rare elements, that agents believed to be acting for the French Government are now in this country in search of deposits from which these metals can be obtained. French agents have also bought uranium ores in the West. The iron ores on which Mr. Edison has been at work with his concentrating plant at Edison, N. J., are understood to contain some molybdenite, and the other metals may be found also when it is known that a demand for them exists.—*Iron Age*.



## BOOK NOTICES.

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*Annuaire pour l'An 1898*, publié par le Bureau des Longitudes (pp. 613, 147).  
Paris : Gauthier-Villars et Fils. (Price, 1 fr. 50 c.)

The astronomical data in this volume of the *Annuaire* have been revised to date in accordance with the most recent discoveries. Several new charts exhibiting the magnetic elements in France have been contributed by M. Monseaux ; the chapter on tides has been rewritten ; Bertholot's thermo-chemical tables have been brought up to date, and a number of other valuable and interesting communications are included in the volume. W.

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*Annuaire de l'Observatoire municipal de Montsouris pour l'Année 1898*  
(pp. 636). Paris : Gauthier-Villars et Fils.

This volume is devoted to an account of the observations made during the year 1896 by the several scientific bureaus under the direction of the Municipal Council of the city of Paris. They cover the branches of meteorology, chemistry, microscopy and hygiene, and may be studied with much advantage by all who are interested in subjects pertaining to public health and municipal administration. W.

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*Institute Organization* : the plan and scope of the Brooklyn Institute, and its application to other cities. By Barr Ferree.

The above is a publication, in pamphlet form, of a paper presented by the author to the President and Council of the Brooklyn Institute. Mr. Barr Ferree gives a concise statement of the plan of organization and the methods employed by this Society, and offers some suggestions for the further extension of its work.

The remarkable growth of this notable organization, from a membership in 1888, of 82, to nearly or quite 5,000, at the present time, affords the most convincing evidence that the advantages it offers to the public by its educational methods are real. Notwithstanding its recent phenomenal growth in membership, the present rate of increase promises an even greater growth for the immediate future, the admirable flexibility of the organization permitting of an indefinite extension of its popular educational features. It is gratifying to know that the good work accomplished by the Institute has been recognized by the municipal authorities by the gift of a splendid museum building which will shortly be ready for occupancy. W.

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*Conclusions of the French Commission in Reference to Tests of Cements. The Influence of Sea Water on Hydraulic Mortars.* (Translated from the French and from the German by O. M. Carter, Captain Corps of Engineers, U.S.A., and E. A. Gieseler, U. S. Assistant Engineer. Washington : Gov Print. 1897. 8vo. Pp. 77.

The first of these contributions contains the conclusions approved by a technical commission appointed by the Ministry of Public Works of France,

"to formulate uniform rules to be followed in testing materials of construction," etc. The contribution embraces the work of Section B, of the Commission, which was charged with the study of the questions relating to materials of construction other than metals, and is confined to the study of the methods of testing masonry materials, namely, cements, limes, pozzuolanas, sands and plasters.

The second contribution embraces several articles named below, viz.: The Influence of Sea Water on Cements, by Dr. Wm. Michaelis, a widely recognized authority on the subject of cements; a reply to Dr. Michaelis' article by the Board of Directors of the Union of German Portland Cement Manufacturers; and a paper on the same subject, by E. Coudlet.

The papers are all valuable contributions to our knowledge of the properties and behavior of these indispensable materials, and may be commended to the attention of engineers of public works, W.

*The Elements of Electric Lighting*, including electric generation, measurement, storage and distribution. By Philip Atkinson, A.M., Ph.D. Ninth edition. New York: D. Van Nostrand Co. 1897. 8vo. Pp. 289. Price \$1.50.

Mr. Atkinson's "Elements of Electric Lighting" has been generally received as one of the best popular expositions of the subject adapted to the needs of the non-professional reader. The fact that a ninth edition has been found needful speaks for itself of the utility of the book.

In the present edition important changes have been introduced in the chapters relating to the construction of dynamos, to conform to the progress of the past few years. Other changes will be noted in the consideration of the subject of storage batteries; the vacuum-tube system of lighting receives a share of attention, and numerous other references to the most recent advances in the application of electricity to lighting will be found incorporated therein. W,

*Jahrbuch der Elektrochemie*. Berichte über die Fortschritte des Jahres 1896. Dr. W. Nernst und Dr. W. Borchers. 3ter Jahrgang. Halle a. S. Verlag von Wm. Knapp. 1897. 8vo. Pp. 359, with numerous illustrations.

To manufacturers, electrical engineers and students the year-book of Nernst and Borchers affords the only comprehensive digest of current progress in the field of electro-chemistry, and it covers the ground very satisfactorily. This special branch of applied electricity is growing rapidly, and its importance in a few years more will be vastly greater than at present. W.

*The Elementary Principles of Machine Design, etc.* By J. C. A. Meyer. New York: The Industrial Publication Company. 1897.

The office of this work is to serve the young mechanic as a guide in the practice of machine designing. It appears to be very well adapted to serve the author's purpose. W,

*Sanitary Engineering.* By Wm. Paul Gerhard, C.E. New York: The Author, 36 Union Square, East. 1898. 12mo. Pp. 132.

This work is a reprint in book form of a lecture delivered by the author before the Franklin Institute in 1895, and published in the *Journal*. Appended thereto is a paper entitled "The Work of the Sanitary Engineer in Time of Epidemics, in Time of War and in sudden Calamities in Civic Life," contributed originally by the author to the *Sanitarian* (1895). The material included in the book is a comprehensive and masterly exposition of the scope and limitations of sanitary engineering and of the duties and responsibilities of the sanitary engineer.

W.

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*A Short Hand-book of Oil Analyses.* By Augustus H. Gill, S.B., Ph.D. Philadelphia and London: J. B. Lippincott Co. 1898. 12mo. Pp. 139. Price, \$1.50.

The above work is a concise manual, setting forth the most approved methods, physical and chemical, for the testing of oils, and, though primarily designed for the use of students of applied chemistry, will be found extremely serviceable to the practical chemist where more elaborate works on the subject are not accessible.

W.

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*Practical Electricity: A Laboratory and Lecture Course, etc.* By W. E. Ayrton, F.R.S., Assoc. M. Inst. C.E. Volume I, "Current, Pressure, Resistance, Energy, Power and Cells." With 247 illustrations. London, Paris and Melbourne: Cassell & Co., Limited. 1896. Price, 9s.

This is an entirely rewritten, enlarged and modernized edition of a well-known and valuable text-book for electrical students.

W.

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*Elements of the Differential and Integral Calculus*, with explanations. By Wm. S. Hall, E.M., C.E., M.S., etc. New York: D. Van Nostrand Company. 1897. 8vo. Pp. 249. Price, \$2.25.

This book is described by the author as designed for the use of colleges and technical schools as an introduction to the study of the calculus, and he has endeavored so to present the subject as to adapt it to the needs, not only of the student of mathematics, but also to those of the engineer who may wish to make application of the calculus in his work.

W.

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*The Strength of Materials.* A text-book for Manual Training Schools. By Mansfield Merriman. Fourth edition. New York: John Wiley & Sons. London: Chapman & Hall, Ltd. 12mo. Pp. 124. Price, \$1.00.

In the treatment of the subject in this work, the author presupposes on the part of the student of such mathematical knowledge as is usually imparted in the high-school courses, embracing arithmetic, algebra, geometry and elementary mechanics. It should prove a useful adjunct to the course of study in the Manual Training Schools.

W.

## Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, March 16, 1898.*]

HALL OF THE FRANKLIN INSTITUTE,  
PHILADELPHIA, March 16, 1898.

MR. JOHN BIRKINBINE, President, in the chair.

Present (estimated) 350 members and visitors.

Additions to membership since last report, 15.

The Secretary reported the resignation of Mr. Wm. C. Henderson from the Committee on Science and the Arts. A special election was held to fill the vacancy, and resulted in the election of Prof. George F. Stradling.

Mr. Chas. E. Tripler, of New York, gave an account of his method and apparatus for liquefying the difficultly-condensable gases, and made a large number of experiments with liquefied air.

Of these, the more noteworthy were the behavior of the liquid under different conditions; the freezing of a great variety of substances; the characteristics of matter at the extremely low temperature of the liquid; the remarkable effects of the low temperature on the physical properties of metals, etc.

At the close of Mr. Tripler's demonstrations, which were extremely novel and of the highest interest, the meeting gave him a vote of thanks, and the subject of his system and apparatus was referred for investigation and report to the Committee on Science and the Arts.

Adjourned.

WM. H. WAHL, *Secretary.*

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### COMMITTEE ON SCIENCE AND THE ARTS.

*Stated Meeting March 2, 1898. No quorum. Adjourned.*

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### SECTIONS.

MINING AND METALLURGICAL SECTION.—*Stated Meeting February 9, 1898.*  
Address of the retiring President, Mr. Benjamin Smith Lyman.

In laying down the office of President of the Section, I beg not only to thank you warmly for your kindly consideration during the past year, but to say a parting word or two on the scope and policy of the Section.

The Sections of the Franklin Institute have been established with the expectation of effectively promoting applied science of every kind by the inducements they offer men to undertake and make public and discuss original investigations of importance. The sagacious secretary of the Institute has long cherished and often expressed the hope, and apparently with excellent reason, that eventually the whole original scientific work of the Institute may be done through a considerable number of Sections, each cultivating its own field, and all harmoniously coöperating. Some progress has already been made towards establishing the Sections, and it seems probable that more of them may soon be started with advantage. Certainly, they are such useful

and effective means of carrying out the manifold purpose of the Institute that their formation and growth ought to be zealously furthered.

In order to encourage them, it seems desirable that their good work should not be hidden away out of sight, but should be made duly conspicuous to the whole Institute and to the world; and that it should be distinctly seen and acknowledged that they are the great constituents of the Institute, so far as the Institute undertakes to extend the bounds of applied science and the allied arts. If the Sections are best able to do the scientific work of the Institute, they also best know, each in its own branch, the needs of the Institute, and therefore deserve to have, as organizations, an important share in the management of the whole Institute. They should be not merely a sort of safety-valve for the harmless and unnoticed escape of superfluous zeal, but coöperating engines for more effectively and honorably utilizing the supply of power. It seems that the Institute will in time become essentially a combination or federation of Sections, as the United States is a federation of States; and that each Section should have its share in the management of the whole organization, either by equal representation in a Senate, a new coördinate governing body, or by a certain representation in the present Board of Managers. The Sections are as capable of wisely electing members of the Board as the general monthly meeting can be.

Each Section, moreover, has its own interests to promote within the Institute. For example, in our Section, we hope to establish an important museum of objects connected with the mineral industry, and we have consequently the strongest interest in obtaining from the Institute the proper space and means for arranging such a museum at the earliest possible moment. We ought therefore, as an organization, to have a voice in the disposal of any space or any funds that may be possibly employed for such a worthy purpose. At present we have, as a body, no representation whatever in the Board of Managers, and it seems only fit that, for the proper and effective prosecution of our reasonable demands in furtherance of the objects of the Section, we should have distinctly and of right some official representation in the management of the Institute.

Another very important means of increasing the usefulness of our Section is the encouragement of the social side of our meetings. Of course, the most vital point is to have valuable original papers and useful discussions of them; but the greater the certainty of an agreeable social chat after the serious work of the evening, the more sure is the gathering to be a large one, and consequently the better the inducement to prepare and read important papers. Besides, rather obviously, there are other very weighty benefits, both for personal advantage and for the promotion of science, to be derived from friendly social intercourse between the members of the Section. Every member or visitor who makes it a practice to stay awhile and chat after the adjournment helps towards that highly useful social feature of the meeting. It is hoped that before long we may emulate the Electrical Section, and give still further encouragement to the social side of the meetings by having some slight refreshments provided after the adjournment, to keep the hungry and thirsty in good sociable humor and prevent them from hurrying away too speedily. When the changes in the arrangement of the library have been completed, a few weeks hence, the main reading-room and museum will be a splendid

place for such social gatherings. Here, again, we shall perhaps need official representation in the management of the Institute, in order effectively to advance our wishes as a body.

Heartily congratulating the Section on its having obtained so excellent a chief for the present year, I have now great pleasure in calling upon Mr. Outerbridge to assume the presidency of the Section.

*Stated Meeting*, held Wednesday, March, 9, 1898. President, Mr. A. E. Outerbridge, Jr., in the chair.

Mr. James S. De Benneville was elected Secretary of the Section for the current year.

The President named the following standing committees for the year :

On Papers : Messrs. Benj. Smith Lyman, James Christie and Jas. S. De Benneville.

On Finance : Messrs. Joseph Richards, Henry G. Morris, and F. Lynwood Garrison.

The following new members were enrolled : Messrs. J. Selgreaves Cox, Robert B. Haines, Jr., and Harrison Souder.

Mr. Robert W. Lesley presented a paper, entitled "The Development of the American Portland Cement Industry," which was discussed by several members and others. The thanks of the meeting were voted to the speaker, and the paper with discussion was referred for publication in the *Journal*.

*Special Meeting*, held Wednesday, March 23, 1898. President Outerbridge in the chair.

Prof. Alexis A. Julian, Columbia University, New York, presented a communication entitled "Building Stones: Elements of Strength in their Constitution and Structure." The paper was illustrated by the projection of thin sections, with the aid of the lantern microscope. (Referred for publication.)

CHEMICAL SECTION.—*Stated Meeting* held Tuesday, March 15, 1898. President, Dr. Lee K. Frankel, in the chair.

Mr. G. Morgan Eldredge read a paper entitled "A Method of Applying a Money Standard to the Nutritive Values of Feeding Stuffs, to which is Appended a Mode of Constructing a Balance Ration." The paper was discussed by Mr. Kebler and the author.

Mr. Paul R. Heyl read a brief communication "On a supposed Change of Weight with Change of Temperature," describing an apparatus which he had devised for an experiment bearing on the subject. The communication was discussed by Dr. Keller, Dr. Hall, Mr. Lee and the author. Referred for publication.

Mr. Aron Hamburger presented a communication on "Recent Developments in the Textile Industries," describing new methods for imparting a silky lustre to wool, various novel applications of formaldehyde, etc., etc. The subject was discussed by Dr. Keller and the author. Referred for publication.

ELECTRICAL SECTION.—*Special Meeting* Tuesday, March 1, 1898. President, W. E. Harrington, in the chair.

Professor Arthur Goodspeed, University of Pennsylvania, gave a lecture on "Recent Advances in Radiography," profusely illustrated with lantern views.

W.

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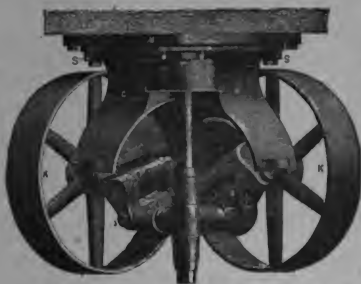
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# THE JOURNAL OF THE FRANKLIN INSTITUTE

DEVOTED TO

**\*Science and the Mechanic Arts.\***

EDITED BY

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FOR THE PROMOTION OF THE MECHANIC ARTS.

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73D YEAR.

MAY, 1898

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THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

## Mining and Metallurgical Section.

*Stated Meeting, December 8, 1897.*

### FATIGUE OF METAL IN WROUGHT IRON AND STEEL FORGINGS.

BY MR. H. F. J. PORTER.

The Bethlehem Iron Company, South Bethlehem, Pa.

*(Concluded from vol. cxlv, p. 261.)*

The product of the open-hearth furnace (*Fig. 9*) is found to give most eminent satisfaction, and has been generally adopted for making forgings.

In order that the metal of a forging should be thoroughly worked to give it strength and toughness, the ingot should be cast approximately twice its diameter. Besides this increase in diameter there is added from 10 to 25 per cent. to its length, for reasons which I will try to make apparent.

There are various defects which are inherent in steel ingots. In the first place, when pouring metal into the mould, air is apt to be entrained and cause "blow-holes." In the next place, at certain stages of the cooling process gas is generated, and will cause blow-holes of itself. There are several ways of over-

coming these defects, but without doubt the most efficient is what is known as the Whitworth process of fluid compression. In this the mould is placed on a platen and is run underneath a hydraulic press. This press has a capacity of over 7,000 tons (*Fig. 10*), and under this enormous pressure the air which has been entrained in the pouring is forced out through joints in the mould, where vents have been left for that purpose, and the gases which are apt to form in the cooling of the mass are prevented from generating. *Fig. 11* shows an ingot after being taken from the mould.

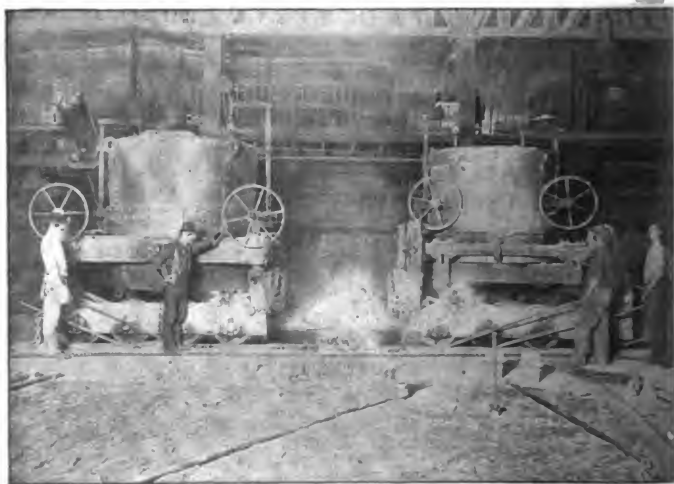


FIG. 9.—Casting an open-hearth ingot.

Another defect which is apt to occur in an ingot is known technically as "piping." The metal, when it is poured into a mould, cools and solidifies first at the surface of the mould, and as the solid metal keeps cooling towards the center, it shrinks and draws away from it. We have, if you can imagine such a thing, a pot with metal in it, which is really not sufficient to fill it properly, but which is being drawn out in all directions to fill it. This shrinkage draws principally from the

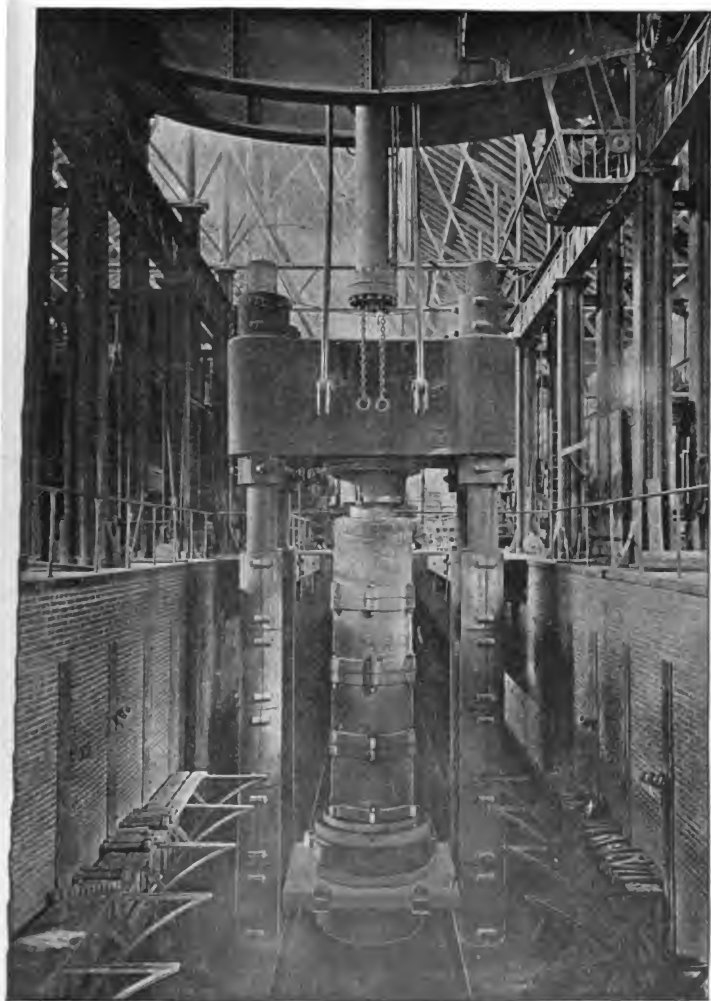


FIG. 10.—7,000-ton fluid-compression press, with ingot mould under press,  
Bethlehem Iron Company's Works.

center and from the top, these being the parts that solidify last. It is, therefore, to take care of this shrinkage that more metal is added to the length of the ingot than would otherwise be required. The hydraulic pressure applied at the top forces the fluid metal from this added part down through the center, and thus we are enabled to keep the latter filled where otherwise we would have a cavity or "pipe." The section of shaft on the right-hand side of *Fig. 8* shows an excellent example of "pipe."

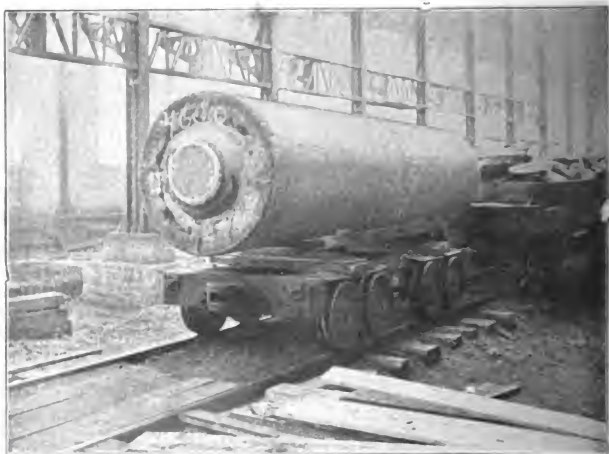


FIG. 11.—Solid fluid-compressed ingot.

Still another defect which is apt to occur in ingots, and especially in those of very large size, is what is known as "segregation." This is partly a mechanical and partly a chemical separation of the various ingredients of steel (sulphur, phosphorus, manganese, silicon, etc.), each of which has its own temperature of cooling. As the mass cools the tendency of these ingredients is towards the central and upper portions where it cools last, thus forming a central core of impurities. This does not occur to such a great extent in small ingots, but in all large ingots it does occur, and even this process of "fluid

compression" does not entirely prevent it. It does succeed, however, in giving us a perfectly solid piece of steel, with the exception of "segregation" in large ingots, and that defect I will show later can be taken care of. It is necessary that we should have an absolutely solid ingot at the beginning, because steel will not weld, and if we have any defects in the



FIG. 12.—70-ton ingot reheated and ready for forging.

ingot to start with, they cannot be remedied later by hammering, as might be the case if we were dealing with iron, which possesses to the highest degree the property of welding.

The extra length, having served its purpose of supplying metal to fill "blow-holes" and "pipes" and of collecting "segregation," is cut off and returned to scrap. The ingot is then ready for the forging process.





FIG. 13.—The Bethlehem Iron Company's 14,000-ton hydraulic forging press. This press is served by a 15,000 horse-power pumping engine.



The first operation in the process of forging is the reheating of the ingot. This operation is a very delicate one, as great care must be taken to make the heat penetrate the metal slowly and uniformly (*Fig. 12*).

As already explained, the metal in the ingot during the process of cooling is being drawn out in all directions to fill the mould. When it is cold, therefore, it is in a condition of strain throughout its interior. If we were to put a cold ingot into a hot furnace to be reheated, we would immediately expand the surface metal and pull it still further from the center, and thus put an additional strain on the inside metal. In very large ingots cracks are thus apt to be started in the center and forgings are very liable to break in subsequent service, from the fact that they have not been properly reheated. A great many forgings fail from lack of care being taken at this time.

Next comes the forging process proper, and one of the first requisites is the proper selection of forging tools. The pressure applied in shaping a piece of steel should be sufficient in amount and of such a character as to penetrate to the center and cause flowing throughout the mass. This flowing of the metal requires a certain amount of time, and the requisite pressure should be maintained throughout a corresponding period. The hydraulic press (*Fig. 13*) fills these requirements exactly. The evil effects produced by the rapid impact of light hammers have already been shown (*Fig. 4*), and undoubtedly their use should be avoided. Under the slow motion of the press time is allowed for the molecules of the metal to move easily and the pressure is felt all through the forging. *Fig. 14* shows the appearance of the end of hydraulically-forged shafts. The center being the hottest, and therefore softest, is squeezed out, and gives the convex shape shown. The forging in *Fig. 15* show this bulging appearance very plainly. During the forging process, in which there is a gradual reduction in diameter and increase in length, a great deal of work is put into the metal (*Fig. 16*). In order that the metal should be



FIG. 14.—Effect of forging under a heavy press.

worked at the proper temperature, it is necessary to reheat it a number of times, and every time a blow is made by the press the metal is worked under conditions differing from those existing when the preceding blow was made, because it has cooled a little in the interval. As, therefore, when finished, no two parts of the forging have been treated the same, it is



FIG. 15.—Nickel-steel conning tower for Battleship Brooklyn, showing effect of press forging. O. D.,  $93\frac{3}{4}$ " ; I. D.,  $76\frac{1}{2}$ " ; length, 119".  
Rough forged as shown, weight 77,600 pounds.

natural to suppose that it is full of forging strains. It is also apt to have cooling strains in it, due to the fact that it has been reheated from time to time in different places, as the forging process passes from one end of the piece to the other. To relieve these various strains, all forgings should be subjected to a final heat treatment called "annealing."

Let us consider the *rationale* of this heat treatment a little more at length.

If we note the rate of cooling of a steel ingot from the point of solidification to coldness, we will see that the temperature will fall regularly the same amount in equal divisions of time until between  $1,300^{\circ}$  and  $1,200^{\circ}$  F. a point (depending on the carbon content) is reached where the temperature suddenly stops falling and for a time either remains stationary or perhaps rises for a short time, and then the rate of cooling continues



FIG. 16.—Ingot in process of being forged into a shaft.

regularly. This point, where the change of rate takes place, is called the “recalescent” point, and from chemical and physical tests we know that a change in the structure of the steel occurs here. (*Fig. 17.*)

The fluid steel begins to crystallize at the point of solidification, and the slower the rate of cooling from there down the larger the crystals will be when the ingot is cold. At the point of recalescence, however, it would seem as if the crystallization, so to say, locks itself, for, after the ingot has become

cold, if we reheat it to a temperature below this point, on again becoming cold we will find that the crystallization is not affected, but if we reheat it a little above the recalescent point, when it is again cold the crystallization will be found to be much smaller than before.

In fact, it is known that if steel is heated slightly above the recalescent point all previous crystallization is destroyed, and a fine amorphous condition is produced at that temperature. As soon as cooling begins again crystallization sets in, and continues until the ingot is cold. As, however, the time of cooling from the recalescent point is comparatively short, the resultant crystallization is correspondingly small. It can be

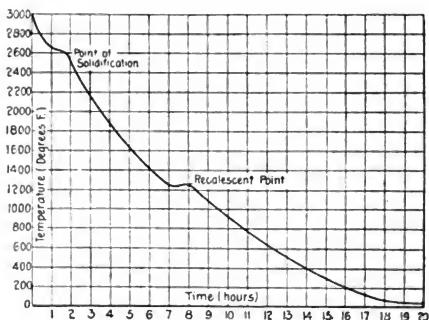


FIG. 17.—Cooling curve of steel.

readily understood that when heat treatment can completely change the internal condition of steel, it should bear an important part in the manufacture of forgings made of that metal.

Let me for a moment consider the changes which take place in the condition of the metal as it passes through the forging process. Beginning with the cold ingot (which we will assume has cooled slowly and is, therefore, composed of large crystals), we first reheat it up to a forging temperature of from 1,800° to 2,000° F., thus passing through the recalescent point, destroying all crystallization and producing an

amorphous condition. As we put it under the forging press it begins to cool, crystallization at once setting in; at the same time, however, we begin to work the metal.

The work of forging tends to check crystallization, just as disturbing water which is below freezing point will delay the formation of ice crystals. The work of forging may or may not continue (depending upon the size and shape of the finished piece) until the temperature has fallen below the recalcrescent point, but during this time more or less crystallization has occurred, and has been disturbed and distorted. The work of forging has, moreover, proceeded from one end of the piece to the other, the part last worked upon having crystallized considerably before work was applied to it, so that the two ends may be entirely different as far as their internal condition is concerned.

If, as is generally the case, the forging is now considered finished, it is full of pulls and strains about which we know nothing, except that they may amount to several thousand pounds to the square inch. The extent of these strains is made evident when a forging, finished as above described, has a cut taken from it in a lathe or has a keyway cut on one side. The strains in the fibers which are cut are relieved, and the piece invariably springs out of "true." To relieve these strains the forging should be carefully and slowly heated to a temperature slightly above the recalcrescent point and then allowed to cool slowly. By this treatment, which is called "annealing," an entirely new crystallization is established, leaving the molecules of the metal completely at rest. If the forging, on being heated slightly above the recalcrescent point, is suddenly dropped into a bath of cold oil, no time is allowed during the cooling process for crystals to form, and the amorphous condition of its structure at that temperature is retained. This character of heat treatment is called "oil tempering," and is followed by further heat treatment to relieve the metal of any hardening effect due to the cooling process.

An annealed forging has its elastic limit somewhat reduced as compared to its tensile strength, but its ductility is increased very considerably, as shown by its con-

traction and elongation in test pieces. The elastic limit of an annealed forging is invariably less than one-half of the tensile strength. By "elastic limit" I do not refer to the point usually determined by the drop of the beam in an

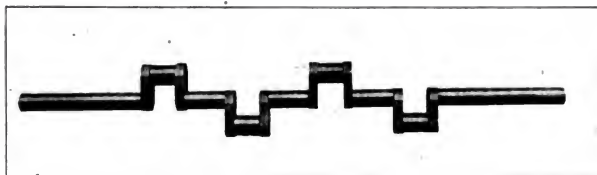


FIG. 18.—Four-throw shaft for gas engine. Shaft,  $4\frac{1}{2}$ " diameter; pins, 5" diameter; length,  $106\frac{3}{8}$ "; weight, 775 pounds.

ordinary testing machine, but rather to the carefully defined point obtained by more accurately determined methods, which is from 2,000 to 10,000 pounds lower. The latter figures are used in all my references in this paper, both as reported by the Government Bureau at Watertown and elsewhere. This pro-

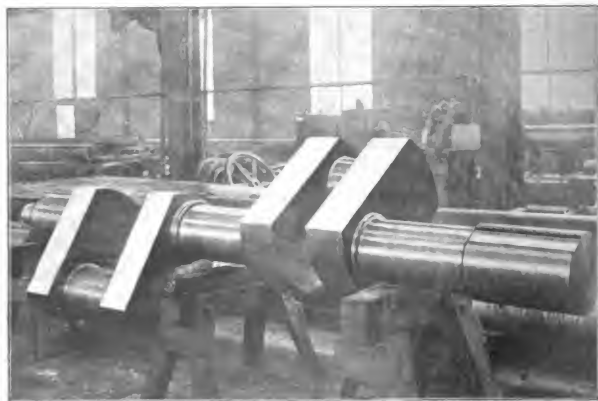


FIG. 19.—Two-throw solid crank-shaft. Diameter of shaft and pins, 12"; length,  $13' 1\frac{1}{8}"$ ; weight, 9,836 pounds.

cess of annealing to relieve internal strains is a very important one. These strains are apt to develop in service, thus constituting an initial load and may throw a forging out of true, or even cause its complete failure, if they happen to act in the same direction as the external working stress.

We have already seen that bars of very high physical properties will not endure indefinitely repeated alternating stresses amounting to 40,000 pounds to the square inch. A forging strain of quite small intensity may easily act in conjunction with an external stress, closely approaching the elastic limit and bring the total working stress up to a load which, acting continuously, would soon cause failure.



FIG. 20.—Connecting-rods for reversing rolling-mill engine. Weight of small rod, 6,750 pounds ; weight of large rod, 10,860 pounds.

It is very evident that the twisting and other manipulation necessary in shaping the forgings, shown in *Figs. 18* and *19*, will leave strains in the metal which, unless relieved by annealing, will cause failure in service. The great mortality of this character of forgings is in part due to the fact that they have not received this heat treatment.

All steel forgings should be finished with good-sized fillets at all corners. In the forgings shown in *Fig. 20*, special care should be taken to have the four corners of the eye in the head well rounded to resist the tendency to crack at these points

should the crosshead- or crank-pin heat up and bind in the brasses.

The lowering of the physical properties by the process of annealing may be corrected by a subsequent treatment of "oil tempering."

In this treatment the forging is first reheated to a definite temperature in a vertical gas furnace, then taken out and dropped suddenly into a bath of cold liquid, which may be



FIG. 21.—Three-throw "built-up" crank-shaft. Fluid-compressed steel, hollow, oil-tempered, O. D., 11"; I. D., 4"; length, 19' 11"; weight, 12,100 pounds.

composed of oil or any suitable fluid. The forging must be subsequently annealed, as before, to relieve it of cooling strains. The hardening effect of the sudden cooling is accompanied by a "setting" of the amorphous condition brought about by the first heating, with the result that the irregular and often coarse crystalline condition existing after forging is broken up and a uniform and finer grain ensues. By the subsequent annealing, strains are relieved and the hardening



effect of sudden cooling is removed to a desired degree; at the same time the elastic limit is increased proportionately to the tensile strength and a greater toughness is imparted to the metal, as shown by a higher elongation and contraction of area in test pieces.

In order to successfully temper a piece of steel, great care must be taken both in the process of reheating it and also in cooling it in the bath. In reheating it, the surface metal is apt to expand away from the center and thus cause cracks in the latter, as previously explained; and in dropping it into the cold bath the surface metal is apt to contract onto the center to such an extent as to cause cracks in the former. In order, therefore, to successfully temper a forging, it should be hollow.

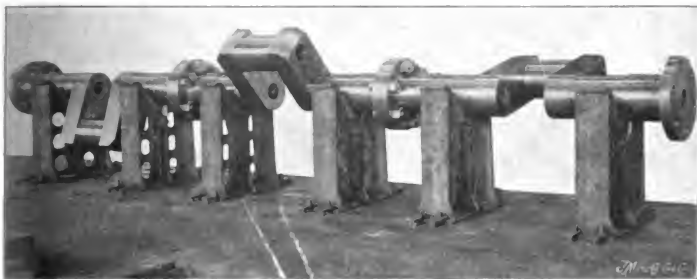


FIG. 22.—Three-throw "interchangeable" crank-shaft for U. S. Battleship Iowa. Length of each crank section, 9.6"; O. D. of pin and shaft, 16"; I. D., 7½"; weight, 8,600 pounds.

By taking out the center it can be reheated without danger of cracking, because the center metal is absent and the heat gets into the interior and expands both it and exterior together. Also, in dropping it into the cold bath there is no solid center on which the surface metal is contracted, and in that way the danger of cracking the surface during the cooling process is eliminated.

The crank-shaft shown in *Fig. 21* is known as a "built up" shaft, the shaft and pin sections being forged separately and forced into the webs or the webs are expanded by heat and shrunk on to them. The crank-shaft shown in *Fig. 22*

is on the contrary known as the "solid" type, shaft, pin, and webs, being forged out of a single block of steel. Engineers are divided in their opinions regarding the relative merits of these two types of shaft. In the built-up type the various parts are small, and can be carefully worked and, if necessary, bored and oil-tempered. The physical properties of the metal can, therefore, be raised to the highest possible limit. The forcing or shrinking process, however, always puts a strain on the metal, which will act as an initial load approaching possibly close up to the elastic limit. In the solid type, on the



FIG. 23.—Fluid-compressed ingot, bored.

contrary, a very large ingot would be required, and as such a crooked forging can not be oil-tempered with safety, the physical properties of the metal cannot be raised by heat treatment. The metal, however, can be relieved of all strains by annealing, and if properly designed should work satisfactorily against externally applied stresses for a very long time.

As stated previously, it is necessary that a forging be hollow in order to temper it.

There are two ways of making a forging hollow. The ordi-

nary way of getting rid of the center of a forging is simply to bore it out. After boring, it is tempered, and thus the strength is restored which was taken away with the metal which was in the center.

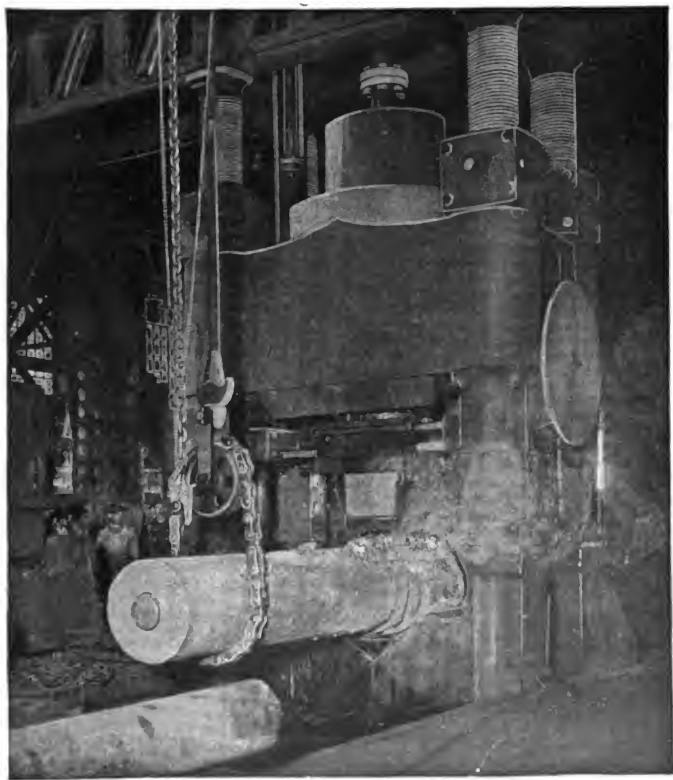
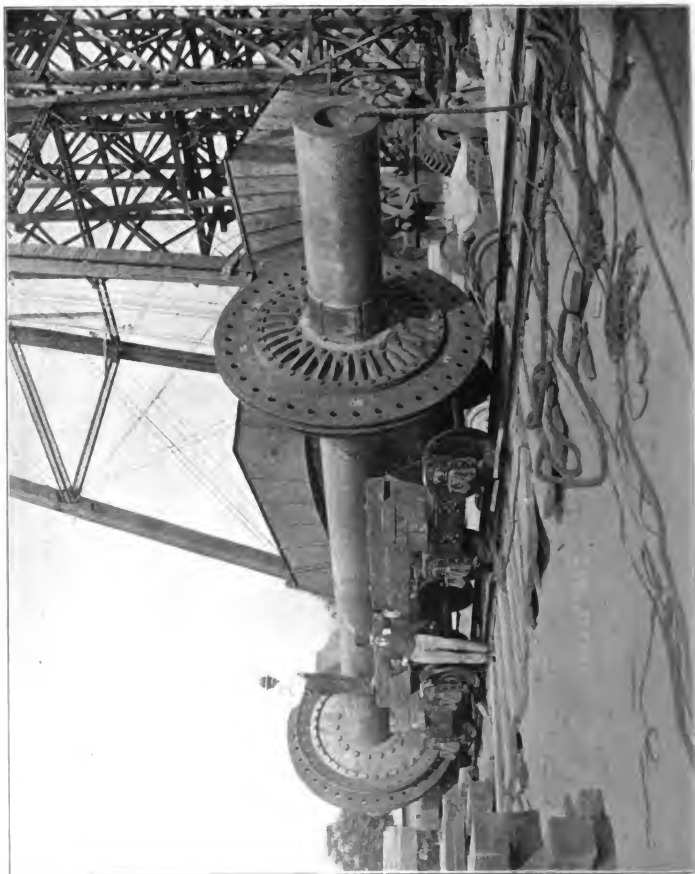


FIG. 24.—Hollow-forging a shaft under a 5,000-ton hydraulic press at the works of the Bethlehem Iron Company.

Another way of getting rid of the center of large forgings is to *forge them hollow*. A person who has not considered the

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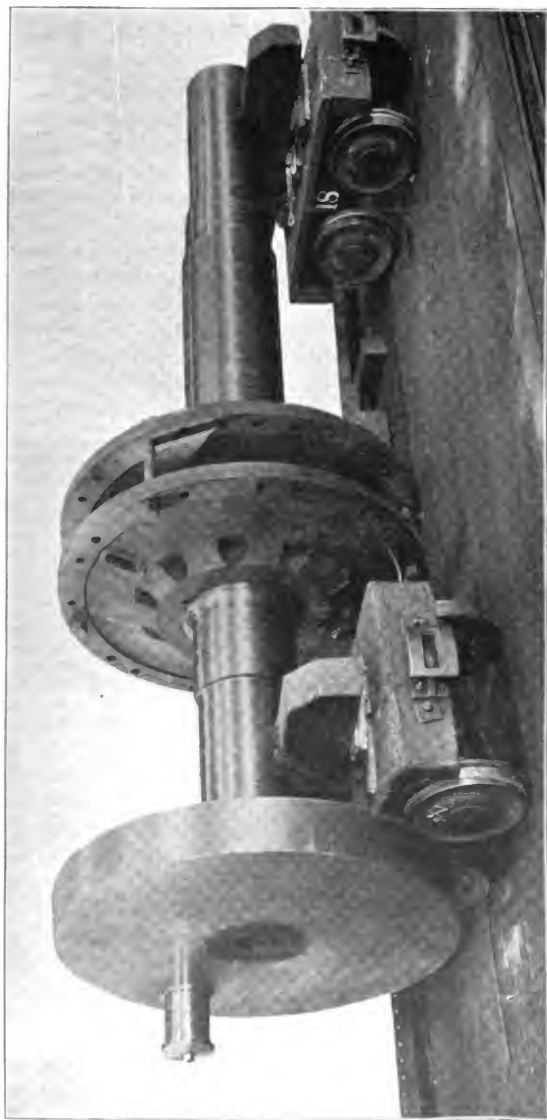


FIG. 26.—Hollow-forged shaft for Corliss Steam Engine Company, of Providence, R. I., for Union Loop Railway, Chicago. Dia. of fly-wheel hub, 28"; Dia. of bearings, 22"; Dia. of axle hole, 9"; length, 21' 9½"; weight of shaft proper, 29,842 pounds.

subject carefully would naturally think that the first thing to do in making a hollow forging would be to cast a hollow ingot. I have already mentioned the fact that there are various defects which occur in ingots, the most serious of which are "segregation" and "piping," and that it is in the center and upper portion where those defects occur. Now, if we were to cast a hollow ingot, replacing the center metal by a solid core of fire-brick or similar material, we would have two cooling surfaces, one on the outside and one around the core, and we would transfer the position of last cooling to an annular ring midway between these surfaces, where we would collect the "piping" and the "segregation." This would not be satisfactory, because the metal there is what we are going to



FIG. 27.—Nickel-steel propeller shaft for U. S. S. Brooklyn. Hollow-forged, oil-tempered, annealed, rough-machined. O. D.,  $17\frac{1}{8}$ "; I. D., 11"; length,  $38' 11\frac{3}{8}$ "; weight, 19,112 pounds.

depend upon for the strength of our hollow forging. We are, therefore, compelled to make our ingot solid as before, to collect the "piping" and "segregation" in the center and at the top, where we have added metal to the original ingot for the purpose.

Then, having cut off the top and thus gotten rid of what "piping" and "segregation" there are there, we bore out the center and so get rid of the "piping" and "segregation" there, and what we have left is as sound and homogeneous a piece of steel as can be obtained (*Fig. 23*).

After the hole has been bored in the ingot, the next process is to reheat it, and, as before explained, this process is not as

delicate a one as if the ingot were solid. The heat affects the center equally with the exterior and the two expand together and we thus do not incur the danger of cracking. When the ingot is reheated, we put a steel mandrel through its hollow center, and, subjecting the two to hydraulic pressure, we force the metal down and out over the mandrel (*Fig. 24*). We thus practically insert into the forging an internal anvil, and we have, therefore, really much less than one-half the amount of metal to work on than we would have if the piece were solid. We have, for instance, in *Fig. 25*, the Ferris Wheel shaft, 32 inches outside diameter, with a 16-inch hole, which leaves only 8 inches of metal to be worked upon between the press and the internal anvil.

A large number of hollow shafts of this type have been made for pumping engines in municipal and mining plants throughout the country, and similar shafts have also been made for engines in street and elevated railway power plants. These shafts have been about 28 inches outside diameter, 11 inches inside diameter and 25 feet long (*Fig. 26*).

The Government requires that shafts for the Navy be hollow, and this custom is being rapidly taken up in general marine practice.

*Fig. 27* shows a hollow-forged nickel-steel shaft, oil-tempered, for the United States Battleship *Brooklyn*.

Test bars cut from this shaft gave a tensile strength of 94,245 pounds; elastic limit, 60,770 pounds; elongation, 25.55 per cent., and contraction, 60.58 per cent.

Professor Merriman is quoted in a paper read before the Society of Naval Architects and Marine Engineers in 1893, by R. W. Davenport, as estimating the strength of these shafts compared to solid shafts as follows, when strained to one-half of their elastic limit:

(1) Propeller shaft United States battleship *Brooklyn*, nickel-steel.

(a) Horse-power transmitted at fifty revolutions per minute, 15,780.

(b) Load in pounds at middle of a span of 12 feet on two supports, 276,200.

(2) Simple steel shaft, solid, 13 inches diameter (same weight as above).

(a) Horse-power transmitted under similar conditions, 5,130.

(b) Load in pounds under similar conditions, 89,000. Comparative strength as 3 to 1.

(3) A solid shaft of simple steel of the same strength as the hollow-forged nickel-steel shaft would be 18.9 inches diameter and weigh 53 per cent. more.

Undoubtedly the best type of hollow-forged shafts, and one which is gradually being introduced, is where the walls are of the same thickness throughout, the outside and inside diameter varying together, both being greatest at the center, where most strength is required, and smallest at the journals



FIG. 28.—Hollow-forged shaft of girder section.

(Fig. 28). Such a shaft is designed on the principle of a girder, and offers the greatest strength for the least amount of metal. Rolls for

plate mills, made after this design, are especially desirable. This type of shaft is being introduced in stern-wheel steamers on the Mississippi and Ohio rivers.

The upper sketch in Fig. 29 shows the type of shaft which is now used on these steamers. It varies from 30 to 40 feet in length and is only from 12 to 14 inches in diameter. It is generally made of wrought iron. In the center is suspended a very large paddle-wheel, and the blow of the paddle on the water makes this center vibrate from  $1\frac{1}{2}$  inches to 2 inches, just such treatment as the bars in the endurance testing-machine are subjected to. This vibration eventually breaks the shaft. Somewhere on this wrought-iron shaft there has been a poor weld, or a part of it is not as strong as the rest, and it breaks there. The shaft shown underneath is of steel, has the same diameter as the other shaft, is forged solid, then bored and oil-tempered. This shaft, although it lasts longer, breaks like the other; it is not stiff enough. The type of shaft which is now being introduced in place of these is shown below. The center has been expanded over a large mandrel, so as to make



that part stiffer. It has the same weight as the first shaft, but is much stronger. Let me give you some comparative figures.

If we represent the strength of a solid wrought-iron shaft 14 inches in diameter and 30 feet in length, as shown by the upper figure, by the figure 1, a solid shaft of steel of the same dimensions would be represented by the figures 1.29; if we were to make it of nickel-steel, its strength would be represented by 2.6. Now, if we were to take the same shaft and simply bore it and anneal it, putting a 3½-inch hole through it, its strength would be represented by 1, just the same as the upper shaft. If we subsequently oil-temper it, its strength would be 1.89. A hollow-forged steel shaft of the same weight

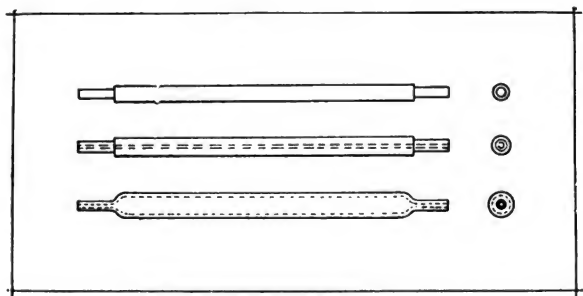


FIG. 29.—Evolution of the modern stern-wheel-steamer shaft.

as the first, but of 22 inches outside diameter, with a 17-inch hole through it, would be represented by the figure 4; if oil-tempered, 5½; if made of nickel-steel, its strength would be represented by the figure 6; and if oil-tempered, by the figure 8.

With the substitution in the trades of steel for wrought iron for engine and miscellaneous forgings, the tendency at first was to use a very mild, soft steel approaching wrought iron in the ease with which it could be handled in the shop, especially in machining.

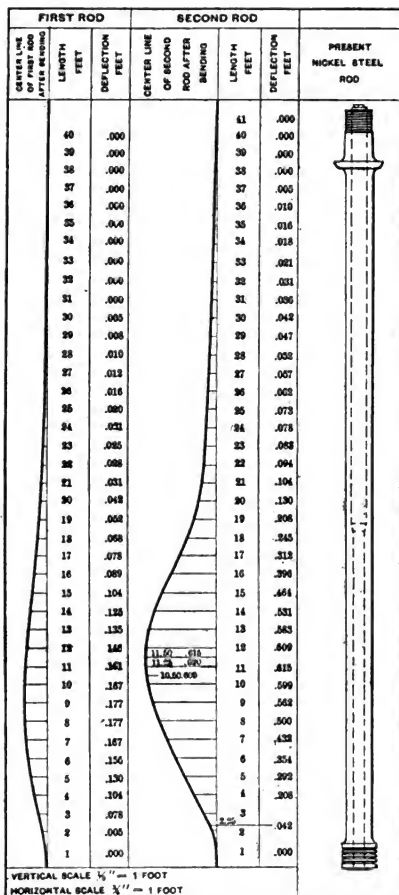
Mild steel, when of good quality, is superior to wrought iron in strength, toughness, homogeneity and freedom from

danger of imperfect welds and porous spots enclosing slag, etc. Still it does not possess the very desirable quality of high elastic strength combined with ductility or toughness in as great a degree as can be obtained without danger in a harder steel when proper precautions are taken in its manufacture.

It is only in recent years that high carbon steel has been found available for forging work. Krupp, of Essen, Germany, was the leader in substituting his soft crucible steel for wrought iron in heavy forgings. After 1870 soft open-hearth steel became a more frequent substitute, with such success that compared with wrought iron the soft steel forgings made by well-known English manufacturers soon attained a high reputation for their quality. It was, therefore, natural that our Government officials, when first issuing specifications for the heavy engine and shafting forgings required for the rebuilding of our navy, followed in the direction of the English practice and called for a steel having a tensile strength of about 65,000 pounds per square inch, and a minimum elongation of about 28 per cent. in four diameters. To-day, however, we are called upon by our Government to furnish a steel for the above purposes which will show a tensile strength of 80,000 pounds per square inch, an elastic limit of 50,000 pounds, and an average elongation of 25 per cent. in four diameters.

The character of steel now used for crank-pins by many railroads furnishes a marked illustration of the practicability of using high carbon steels. When steel was first used in such pins in place of wrought iron, a soft low-carbon steel was generally employed, and the failures due to "fatigue of metal" were almost as numerous as when wrought iron was used. The broken pins showed what has been called "a fracture in detail," a gradual parting of the steel extending inward all around the piece, undoubtedly produced by the working strains repeatedly approaching the low elastic limit of the soft steel. On substituting a steel with an elastic limit of 45,000 to 50,000 pounds per square inch, failures were greatly diminished, without changing the diameter or shape of the pins.

These same facts are true to the present day regarding steam-hammer rods.



\* FIG. 30.—Comparative failures of high- and low-carbon steel piston-rods of 125-ton hammer, Bethlehem Iron Company.

\* By H. K. Landis in *Iron Age*.

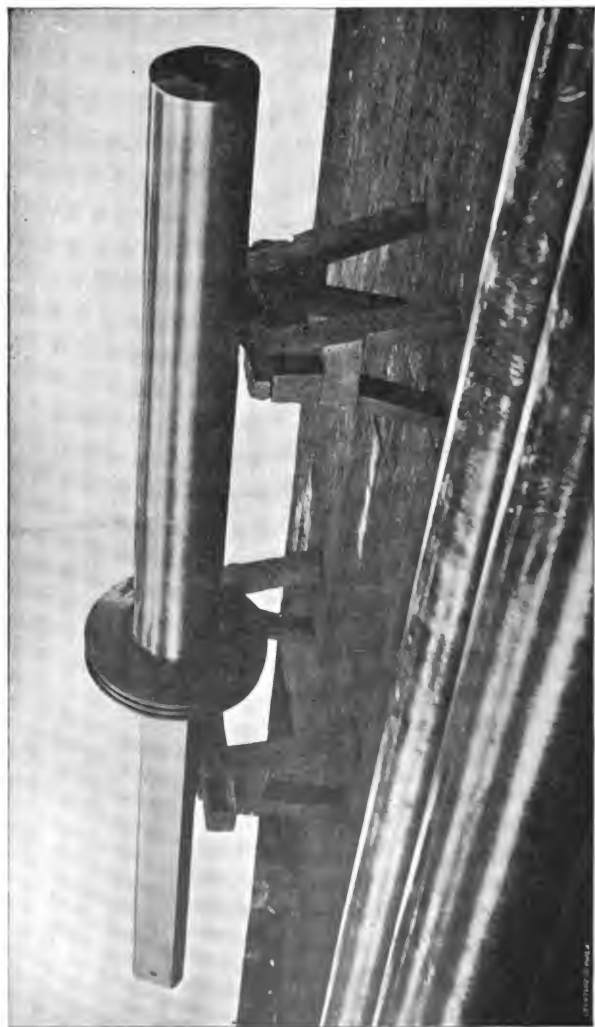


FIG. 31.—Nickel-steel, oil-tempered, hollow steam-hammer piston-rod, with piston forged on. Dia. at lower end, 16"; total length, 18'2 $\frac{1}{4}$ "; weight, 9,522 pounds.

*Fig. 30* shows the experience of the Bethlehem Iron Company with rods for their 125-ton hammer.

The first rod was made from high carbon open-hearth steel, hydraulically forged with a 4-inch hole running through the entire length and having an outside diameter of 16 inches. The failure of this rod was attributed to partial crystallization and to its being of too high carbon steel, and, therefore, too brittle. These were the usual reasons given for failures under similar conditions in those days.

Consequently, the next rod was made with a much lower carbon, in the hope that it would withstand the effects of shock better. This supposition proved to be erroneous, and it failed after a shorter service than the first, and its failure was much more serious.

About this time the advantages of material with high elastic limit became known, and the third rod was made of nickel-steel. The dimensions were somewhat changed, however. The outside diameter was from 16 to 17 inches and the hole was made 8 inches in diameter for 22 feet from the top, the balance was made 7 inches instead of 4 inches, as before. This rod has fulfilled all expectations. The amount of deflection of the two rods which failed is shown in the figure.

*Fig. 31* shows the character of rod now made for users of rods who want something that will last a long time.

In general, it can be stated that experience shows that where high duty is demanded of a forging, mild steel of a tensile strength of 60,000 pounds is not the best material to use, owing to its low elastic limit. The tendency is now towards the adoption of a higher carbon steel, followed by such treatment as will raise the elastic limit relative to the ultimate strength.

Engine builders, although fully alive to the advantages of the use of high carbon steel, are deterred from its use by the fact that it is very tough, and, therefore, the cost of machining in the shops is high. In competition with each other, the engine builder who uses the lower carbon steel can bid lower than the one who uses the better grade. It is, therefore, to the interest of the engineer, who specifies what he wants, to insist

upon his specifications being worded properly, so that all the bidders can base their calculations on the same grade of material.

The engineer does not want his engines composed of a weak and unreliable material merely because the engine builder finds it easier and cheaper for him to manipulate it in shaping. He should follow the progress in steel-making and insist upon getting the best he can afford to buy. The first cost may be a little greater, but he will save by getting a material much stronger and stiffer and which will receive a higher polish. The lessening of friction of such parts will alone pay the difference in cost by the saving in fuel and lubrication.

Experience must teach the engineer what quality of steel is best suited for the various parts of his engines, and his judgment must determine whether he will use a high quality and decrease the size of his forgings or a cheaper grade and put in more metal and take greater risk.

Although forgings can be made to fill a large variety of specifications, they can, in general, be divided into six classes, as follows:

- (1) Mild steel, annealed.
- (2) Medium hard steel, annealed.
- (3) Medium hard steel, oil-tempered.
- (4) Nickel-steel, annealed.
- (5) Nickel-steel, oil-tempered, No. 1.
- (6) Nickel-steel, oil-tempered, No. 2.

Each of these classes is supposed to cover a series of grades of steel, varying in strength several thousand pounds. In selecting the material for the forgings of an engine and in drawing up the specifications therefor, the premise should not be omitted that "all forgings shall be made of open-hearth steel," and that "they shall be carefully annealed after forging."

Large shafts and similar forgings, crank and crosshead pins should be made of fluid-compressed steel, and should be hydraulic forged, not hammered. Wherever practicable, an axial hole should be bored through shafts to insure absence of any internal defects. If forgings are oil-tempered, the hole can be made larger in diameter than if they are simply an-

nealed, and where the hole is 7 inches in diameter and above, they can be hollow forged on a mandrel. A hollow-forged, oil-tempered forging insures the highest attainable qualities, and can be especially recommended where the maximum strength with the greatest lightness is desired.

Where it is important that the quality specified should be obtained in the more important parts, physical tests of the forgings as delivered should be demanded. For such tests prolongations should be left on the end of forgings for the purpose of having test specimens cut from them after the forging and treatment have been completed. Such prolongations should receive no greater reduction than the forging at its largest part.

The following table shows the average physical qualities that should be obtained in forgings made of the several grades of steel mentioned, the test specimens being 2 inches long between measuring points and  $\frac{1}{2}$  inch in diameter and cut from full-sized prolongations of the forgings after treatment; the elastic limit being determined not by the drop of the beam, but by an electric micrometer:

	Tensile strength.	Elastic limit.	Extension percentage.	Contraction percentage.
<i>Simple Steel.</i>				
(1) Annealed . . . . .	58,000	28,000	28	55
(2) " . . . . .	80,000	37,000	23	45
(3) Oil-tempered, with axial hole	80,000	45,000	25	50
<i>Nickel Steel.</i>				
(4) Annealed . . . . .	80,000	45,000	23	45
(5) Oil-tempered, with axial hole	80,000	50,000	25	50
(6) " " " "	90,000	60,000	22	50

I trust that I have been able to make plain in this paper that the causes of failure in forgings are in general to be found either in their design, quality of material or character of treatment in manufacture. Almost all forgings are subjected to alternating stresses. If they are composed of a quality of material which has a high elastic limit, properly proportioned, so that the stresses applied fall well below this limit, and if then they are free from flaws, defects and initial stresses, they should resist fatigue indefinitely.

## DISCUSSION.

MR. G. WHITEFIELD CHANCE:—In Howe's Metallurgy of Steel (p. 198) is cited a case where 18,140 bendings reduced tensile strength from 70,000 to 48,000, and elongation from 20 per cent. to 2.6 per cent.

MR. PORTER:—Mr. Howe, contrary to his usual accuracy of detail, omits to mention what the fiber stress on this bar was. I rather infer that the bar was bent in a vise, or similarly, and that the fiber stress considerably exceeded the elastic limit of the metal; the result quoted would then have been obtained.

MR. CHANCE:—Mr. Howe also says: "Comparing cases in which the stress on each variety is a given percentage of their estimated tensile strength under single load, hard steel breaks down much the earliest." This is a comment on some tests made of the same kind as those you spoke of.

MR. PORTER:—Certainly—this is what my tables show. For instance, in Table No. 2, 34 per cent. carbon steel, with a tensile strength of, say, 90,000 pounds per square inch, and an elastic limit of 42,300 pounds per square inch, stands 14,100,000 revolutions under a fiber stress of 35,000 pounds per square inch or 40 per cent. of the ultimate strength.

Fifty-five per cent. carbon steel, however, with a tensile strength of, say, 100,000 pounds per square inch, and an elastic limit of 47,000 pounds per square inch, stands only about 400,000 revolutions under a fiber stress of 40,000 pounds per square inch or the same percentage of tensile strength.

What I have endeavored to show is that under the *same* fiber stress the higher carbon steel will outlast the lower.

MR. CHANCE:—You mentioned the fact that in the endurance tests the load was within the elastic limit in the extreme fiber, but would the load suddenly applied with high rotative speed be within the limit? We are aware that the suddenly-applied load is very disastrous.

MR. PORTER:—I am not aware that any difference has been observed in the result of fast and slow rotation. In fact, I have been informed that Mr. Howard, at Watertown, has seriously considered putting in a steam turbine, running about



20,000 revolutions a minute, so as to be able to make his tests more rapidly.

MR. PAUL A. WINAND:—There is one point in Mr. Porter's paper which did not seem clear to me. He stated, if I understood him correctly, that specimens, taken from pieces finally broken by fatigue, showed the same tensile strength as the material before being subjected to fatigue.

Now, if this refers to specimens taken from shafts fatigued by rotation under strain, the result may depend entirely on the location in the cross-section from which the specimens were taken. The strain is obviously maximum at the periphery of the cross-section and gradually vanishes at the center. The material near the center has, therefore, not been subjected to appreciable strains, and a test piece taken from that region would practically be in the original condition of the material. Even at some distance from the center, the strains may have been quite below the elastic limit, and the material might stand an unlimited number of reversals of such strains. If, however, the piece has been fatigued by reversals of purely tensile, not bending, strains, it would be immaterial from what portion of the cross-section the test pieces were taken.

MR. PORTER:—The tensile test specimens are annular in shape, the center having been bored out. The outside is 1 inch in diameter, the inside diameter is .9 inch. All the metal to be tested, therefore, has been thoroughly fatigued.

MR. JAMES CHRISTIE:—It might seem unnecessary at this day to demonstrate again the great superiority of steel over wrought iron, for the purpose described by Mr. Porter, except for the occasional complaint of some ultra-conservative, whose thoughts wander back to the good old days, whose faults are apt to be forgotten.

The high speed and great carrying capacity of the modern steamship and railway train, are largely due to the use of good steel in construction, and it is doubtful, if equal results could be had as economically with the old form of wrought iron. We have also passed the era of extreme soft steel, and the tendency is to use harder grades, with the same advantages everywhere, as described by Mr. Porter.

The experiments on fatigue of strength, described by Mr. Porter, are interesting, and give us further information on a subject on which there is yet much to learn.

It is still doubtful if destruction can occur from indefinitely prolonged fatigue, when the stresses are known to be well below the elastic limit. This has been suspected heretofore, but the exact intensity of stress was not always clearly defined. An interesting problem belonging to the physics of steel, is the effect on the material of elastic fatigue. This has been observed in connection with material exposed to prolonged vibration, and is indicated by a loss of elastic energy, after a period of vibration, and restoration by rest.

It may be demonstrated by future experiments, that there exists some intimate connection between elastic fatigue and the fatigue of strength.

MR. PORTER:—If the distinction which Mr. Christie makes between “elastic fatigue” and “fatigue of strength” is respectively fatigue of metal tested *below* and *above* the elastic limit, I can only refer him to Table No. 1 and to the records of endurance tests at Watertown, which are all made under a fiber stress well below the elastic limit.

As far back as 1886 Mr. Benjamin Baker, in his paper presented to the American Society of Mechanical Engineers, in commenting on endurance tests made on material for the Forth Bridge, says: “An illusion entertained by some engineers, that alternating stresses are destructive only if the stress exceeds the elastic limit, is effectually disposed of by these experiments, because none of the stresses in question exceeded the said limit, and some of them were very far below it.”

MR. A. E. OUTERBRIDGE, JR.:—Have investigations been made to determine whether the expansion of the iron ingot mould, caused by the heat of the molten steel, affects the density of the ingot? In other words, do you think it is possible that “piping” may be due, in part, to the receding of the mould from the ingot while the latter is still in a semi-fluid or a plastic condition?

MR. PORTER:—The “sink-head” or added length of ingot supplies metal by ferrostatic head as the mould expands. The

fluid compression prevents piping by adding to the ferrostatic head, and forcing the metal of the sink-head down into the "pipe."

MR. OUTERBRIDGE:—The question was suggested to my mind by my experience with cast iron, more particularly in the special work of casting car wheels. Formerly, a simple "chill ring" was used to suddenly cool the casting and to form the hard-chilled tread of the wheel; this ring expanded when heated by the molten iron, so that, in a few moments, after a wheel had been poured, it was possible to insert a knife-blade between the chill ring and the casting; moreover, the space was usually greater upon one side than upon the other, owing to some accidental cause, such as a draft of air striking one side of the chill ring, and the effect upon the wheel was apparent when it was broken in order to examine the fracture, the chilling effect being deeper on one side than on the other. To overcome these defects, a very ingenious invention was made some years ago, now known as the "contracting chill;" this is a double ring, or rather two concentric rings connected by webs or radial arms, the inner ring being divided, by sawing, or otherwise, into a hundred or more separate segments, each segment being attached to the outer ring by a single arm. When the sectors of the inner ring become heated by contact with the molten metal, they all simultaneously *move inwards toward a common center*, because the radial arms grow longer when heated, and the cold outer ring prevents any movement outwards. This contracting chill, therefore, follows up the casting as it cools and hugs it closely, thus producing a uniform chilling effect upon the periphery of the wheel and preventing annealing of the chilled metal, or return of the combined carbon to the graphitic form. The purpose of my inquiry was to ascertain whether this ingenious principle has been applied to ingot moulds, and if no such experiments have been made, would it seem to you *a priori* likely that a contracting, instead of expanding, iron ingot mould might tend to produce a denser ingot, and thus to prevent or diminish piping?

MR. PORTER:—I am unable to say whether any work has

been done in this direction or not. I imagine not, however, as the large masses of steel usually cast require moulds built very rigidly to resist the enormous internal pressure.

MR. OUTERBRIDGE:—You have spoken of the advantage of hollow forgings and of boring through the center of steel shafts. Can you tell me whether there is any evidence of a release of cooling strains in the shaft traceable to the act of boring the hole?

MR. PORTER:—Yes, most decidedly, a solid shaft may be perfectly straight, but after boring it will invariably be bent. This is true also of turned shafts.

Key-ways, cut in straight shafts, will release strains which will allow the shafts to spring a considerable amount in their length.

Annealing will relieve these strains.

MR. OUTERBRIDGE:—In explanation of this question, I would again refer to cast iron. We all know that a very minute flaw in a cast-iron test bar (such as a tiny blow-hole, or a small piece of slag, sand or dirt) will cause great weakening of the bar, far more than is attributable to the area of the hole or defect. I have found, however, that a hole of quite considerable size may be drilled across the section of a test bar at the point of intended rupture upon the testing machine, and the bar, instead of being weakened, is somewhat strengthened thereby. If a hole  $\frac{3}{16}$  inch diameter be drilled through a bar of 1 inch section, the fracture will often occur through solid metal at one side of the hole. In a number of such tests, I found that the majority of bars with holes drilled across the section were stronger than companion bars, cast in the same mould, not drilled. I have attributed this gain in strength to partial release of internal strains, caused by irregular cooling of the mass, and have heretofore expressed the belief that rearrangement of the molecules takes place in the bar, in a manner somewhat analogous to that which occurs from annealing by heat or from mechanical vibration.

In a car-wheel casting, these cooling strains are enormously increased by the very sudden chilling of the rim, so that a car wheel will explode, or break in two or more pieces with a loud

report, if allowed to cool in the air. After being annealed, a car wheel is the very strongest kind of casting; yet the composition of the metal itself is in no way altered, but the cooling strains have been eliminated.

I have supposed that these cooling strains were peculiar to, or at least excessive in, cast iron, and would not occur to such an extent in steel; therefore, I was desirous to know whether your experience has shown that the act of boring a hole through a steel ingot, or a steel shaft forged from an ingot, has any appreciable effect in increasing its strength by relieving cooling strains.

In conclusion, Mr. President, I wish to add that the paper of Mr. Porter is one of rare interest and importance, and to express my individual appreciation of its value. Although another engagement presses upon me this evening, I have felt unwilling to lose a word of it, and I think, Mr. President, that a special vote of thanks to Mr. Porter should be recorded upon our minutes, and I, therefore, make a motion to that effect.

(Mr. Outerbridge's motion was numerously seconded, and unanimously adopted. The President thereupon formally presented the thanks of the Section to the lecturer.)

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*Stated Meeting, Tuesday, January 12, 1898.*

## SOME ILLUSTRATIONS OF THE INFLUENCE OF GEOLOGICAL STRUCTURE ON TOPOGRAPHY.

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BY BENJAMIN SMITH LYMAN.

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Capt. D. G. Robinson's excellent map of the Punjab Salt Range and of the country northward finely illustrates in many places the influence of the geological structure upon the face of the country. The map was made about forty-five years ago, more particularly for military purposes, and is on the scale of a mile to the inch, with shaded topography. Certain portions of the map are especially interesting from the distinctness of the geological indications.

Near the eastern edge of the map, and about twenty miles northwest of the town of Jhilam, several ridges (*Plate 1*) bend round so as to form the northeastern end of as many concentric ellipses, with the long axis in a northeast and southwest direction. The ridges evidently consist of harder beds of rock separated by softer beds that underlie the hollows between. In the main body of the ellipse the harder rock beds seem to have so steep a dip as to make the beds perhaps nearly vertical and, therefore, nearly parallel on one side to those on the other. But where the principal ridges curve round at the northeastern end of the ellipse, a much gentler dip outwards is shown by the great steepness of the inner slopes and the comparative gentleness of the outer ones. Many of the subordinate outermost ridges have their crests worn down towards the small streams that cut across them, and thereby form sharp little peaks half way between each pair of those streams. The space in the interior of the ellipse of the principal ridges appears to be mainly filled with some level-bedded, probably old-alluvial soft formation. Yet here, too, the small streams have cut down into the steep dipping underlying rocks, and have formed numerous narrow, short valleys parallel to the main ridges, and showing the persistence of the same structure of the older beds throughout the ellipse. It is plain that the ellipse is caused by a saddle in the rocks, and that, if the rock beds of the principal ridges were restored, so as to be continuous over the central part of the ellipse, a form would result, closely resembling an overturned ship or boat, of which the prow would be towards the northeast.

Another place (*Plate 2*) within half a dozen miles east of the Indus, not far from the northwest corner of the map, and about twenty miles southwest of Attock, shows concentric ridges in a somewhat similar oval shape, forming roughly a complete ellipse half a dozen miles long, northwest and southeast, by a mile and a half wide. In this case, however, it is clear, upon careful inspection, that the rock beds do not lie in the shape of a saddle but in that of a basin. For towards the southeast end of the ellipse, and in a less degree along the northeast side, the steep escarpments on the outer side and

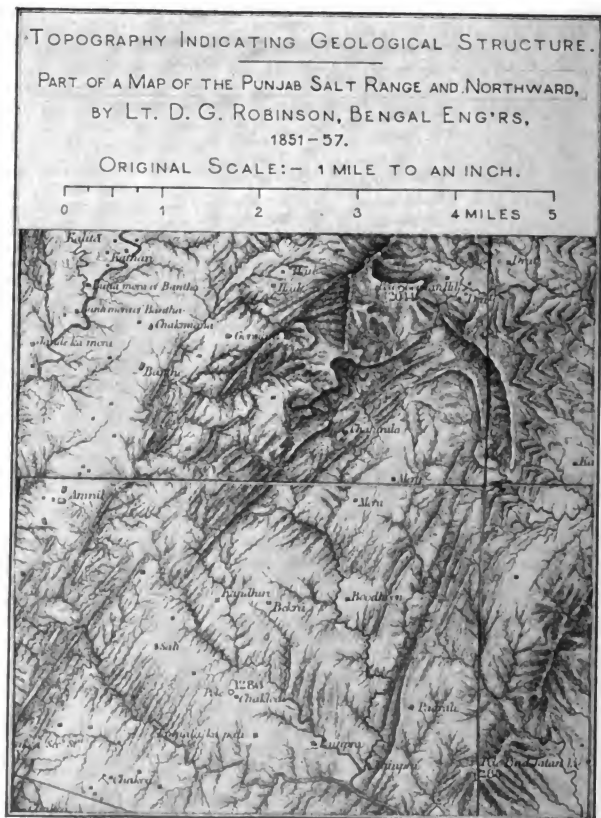


PLATE I.

(*Lyman.*)

## TOPOGRAPHY INDICATING GEOLOGICAL STRUCTURE.

PART OF A MAP OF THE PUNJAB SALT RANGE AND NORTHWARD,  
BY LT. D. G. ROBINSON, BENGAL ENG'RS,  
1851-57.

ORIGINAL SCALE:- 1 MILE TO AN INCH.

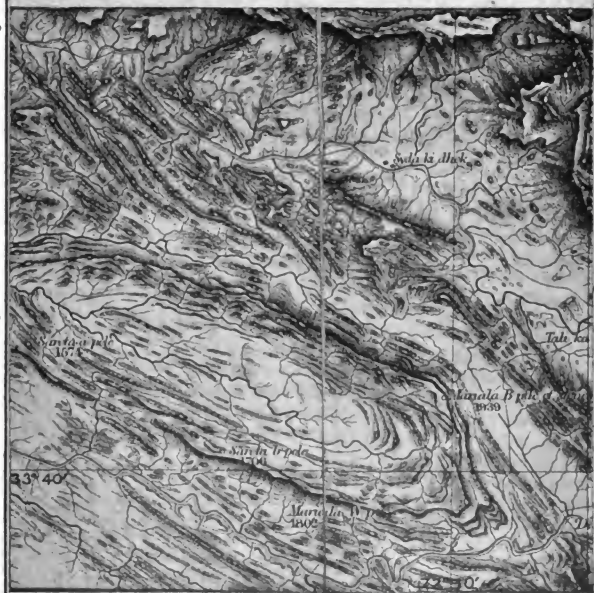
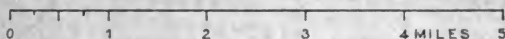


PLATE II.



the comparatively gentle slopes on the inner one show that the dips are towards the center of the ellipse. Along the southwestern side the same thing can likewise be discerned, but the dips seem to be steeper, more nearly approaching the vertical, and continue so for a couple of miles to the southwest, where the lower rock beds become gradually covered up by the overlying alluvium-like horizontal softer beds already noticed. A couple of miles northeast of the ellipse similar indications show that the rock beds form another nearly parallel basin, but the ridges are more broken up, and the geological structure is less easily made out. This basin is distinctly and narrowly closed by ridges on the northwest, but opens out towards the southeast, and the ridges become less continuous and less clear. Between the two basins the rock beds are in the form of a saddle, but very closely pressed together and broken up, so as to leave the geological structure less obvious. It appears, nevertheless, that the saddle broadens out towards the northwest.

Still another place (*Plate 3*) about twenty miles further south, has numerous nearly parallel northwest and southeast ridges, with a couple of the stronger ones bending round at the northwest to form the end of an ellipse. Here again the steep outer escarpments and gentler slopes towards the center show that the rock beds are in basin shape. Along each side of the ellipse they appear to be more nearly vertical, with the two sides rather closely pressed together. Northward from the end of the ellipse the rock beds form a saddle of somewhat irregular shape, and to the northeast another basin, the whole so compressed as to be broken up into rather disjointed parts. The alluvium-like upper soft horizontal beds also reappear here to mask the underlying harder layers.

Yet one more place (*Plate 4*) in the Salt Range itself, near its eastern end, shows a still more varied geological structure within the space of a few miles. At the point marked "Choombi pole" there is a curved nearby rectangular ridge, with steep outer slopes and gentler ones inside, indicating a small basin, broken through along the eastern side by the Bonhar River. The ridges on the east show by their slopes steep,

perhaps vertical, dips; on the west, gentler ones towards the middle of the basin, and on the northwest still gentler, with the crests formed into little peaks between the small transverse streams. To the northeast of the central basin the ridges are roughly concentric, but further on become rather sharply angular in their course, as if crushed together and broken. To the north the main river valley is very much filled up with the same alluvium-like, soft, horizontal beds already noticed, mostly covering up the harder underlying rocks, but leaving some of them visible in short ridges that betray not only steep dipping beds but a continuance of the partly crushed and broken condition of the rock beds of the neighboring hills. Yet some of the principal curves of the more disturbed rock beds are parallel to one another even at a distance of several miles. This illustration has also been used in the discussion of the paper read by Prof. J. C. Branner before the American Society of Civil Engineers last November.

It is evident that the carving out of the strongly-marked ridges and hollows in accordance with the geological structure has been effected by water—the rains and streams—leaving the harder rock beds to stand forth and the softer ones to be eaten away where not protected by overlying hard ones. In that torrid climate the water has acted mainly in its liquid form, with the help of weathering in a moist atmosphere during part of the year, but without the aid of frost to disintegrate the rocks. In some places lime rock may have been to some degree dissolved away by the waters, but their action appears to have been mainly mechanical.

The clear indication of basins and saddles within the small space of a few miles is owing partly to the fact that the succession of rock beds, originally laid down as sand, silt or the like, one on another at the bottom of the sea, and afterwards more or less consolidated, is made up of a great number of not very thick beds or masses of harder rock separated by softer beds that are likewise not in very heavy, thick masses; and partly to the fact that the whole series has been so strongly compressed and is of so yielding a character as to have been crumpled into very numerous, comparatively small waves with

little basins and saddles. These folds are, to be sure, irregularly combined and in many places fractured and crushed into discontinuity. The overlying, more recent, still soft, level-bedded, alluvium-like material of the plains partially masks and obscures the geological structure of the underlying rocks, but is cut through in so many places as not to conceal it altogether. In spite of all the irregular crushing and the occasional concealment, many of the saddles and basins can be distinctly seen, or without great difficulty discerned, thanks to the mainly favorable circumstances.

In the Appalachian region of Pennsylvania the same influence of the geological structure upon the topography is observable on a much larger scale. The successive masses of harder and softer beds are much thicker, the whole series much stronger, stiffer and less readily yielding, and the basins and saddles much more extensive. The irregular crushing and breaking of these great folds is less in proportion to the whole, and the result is in the main an aggregation of comparatively simple regular waves, basins and saddles on a grand scale. The topography indicates those large forms in the same general way as the small ones we have been considering in the Punjab, and has been of great service in the study of the geology of Pennsylvania ever since the days of the first State Geological Survey. The varied topographical effects of the long, narrow basin-form and saddle-form were ably discussed by Lesley and H. D. Rogers forty years ago, when the subject was new to geologists. For the comparatively simple conditions of the Appalachians did not exist in most of the European regions where geological work had been done, and the outcrops of the different geological formations and their structure had been traced out more exclusively by means of their fossils, without regard to the topographical indications, that exist mainly in a less obvious degree.

The first impression was that the Pennsylvania topography had been produced by an immense flood of water, an ocean let loose, flowing over the land and carrying away vast quantities of earth and stones. In those days it was difficult to rid one's self of the idea that great geological changes were almost

instantaneously produced by tremendous cataclysms or even by downright supernatural means or miracles. The idea still lingers among men not familiar with geological matters that some stupendous topographical results have been effected in the twinkling of an eye by the "finger of God"—the expression cited by Prof. Branner. But all geologists now realize that the sculptured relief of the mountains and valleys, even where most astounding, even the gorge of the Niagara or the cañon of the Colorado, has been accomplished in the lapse of thousands of years by the same agents, chiefly rain and streams of water, that we see still in action about us.

It is plain that the geological indications given by the surface topography must have great value of a practical kind, and aid very much towards ascertaining both the general subterranean structure and the smaller details of either theoretical interest or economical importance. If coal or iron ore or other valuable mineral is known to occupy a particular geological horizon, a certain layer in a series of rock beds, such a series, for example, as we have in these Punjab illustrations, the place of outcrop of that horizon or layer, with the useful mineral, may in many cases be recognized merely by means of a careful study of the topography, and often the general structure, whether that of a basin or of a saddle, may be perceived; even though the surface of the ground may be so covered with loose earth and broken stone as to conceal the dips and precise character of the solid rock beds below.

The Punjab illustrations of the influence of the geological structure on the topography are interesting from their showing so clearly the small basins and saddles, with frequently very steep dips, but occasionally gentle ones, and with the repeated alternation of rather thin harder and softer rock beds, partly buried under level-bedded, soft, alluvium-like beds, in a region where the rock beds are in the main very strongly compressed and sharply folded and often broken and crushed together. The map is a striking example of the excellent geological results of faithful topographical work by surveyors who were no doubt quite unconscious of its having any significance for geology.

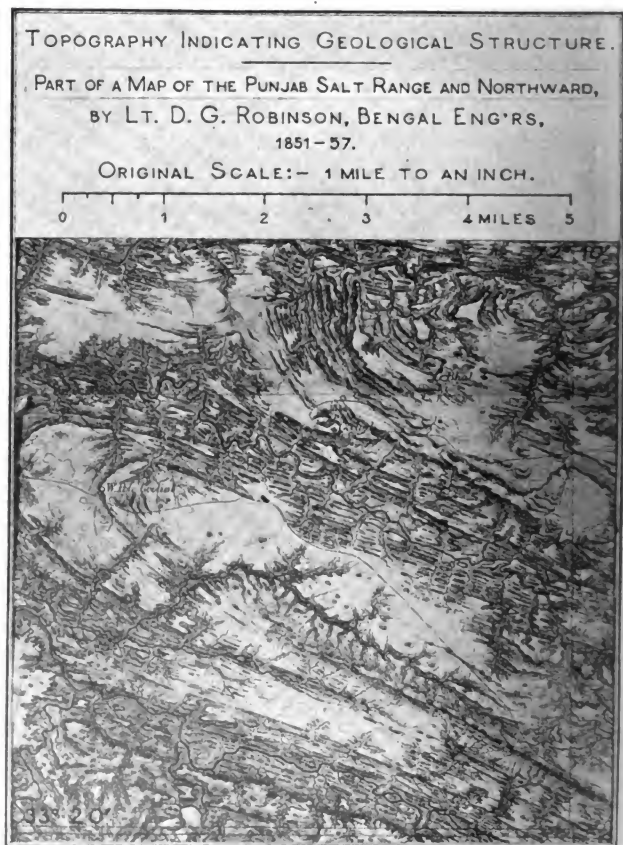


PLATE III.

(*Lyman.*)

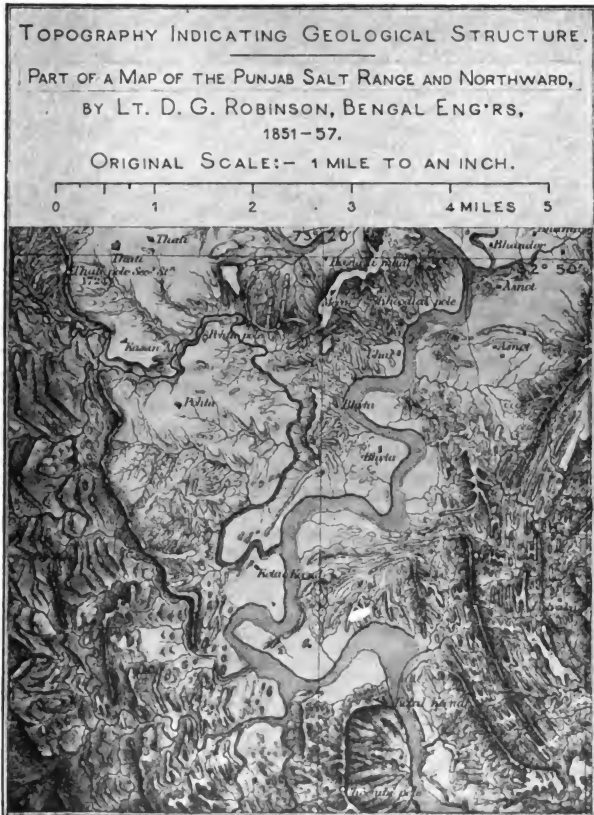


PLATE IV.

## THE FRANKLIN INSTITUTE.

*Annual Meeting, Wednesday, January 19, 1898.*

### TESTS OF THE SYNCHRONOGRAPH ON THE TELEGRAPH LINES OF THE BRITISH GOVERNMENT.

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THE WHEATSTONE RECEIVER OPERATED BY THE ALTERNATING CURRENT IN TRANSMITTING INTELLIGENCE.

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BY

ALBERT CUSHING CREHORE, PH.D.,  
Assistant Professor of Physics, Dartmouth College,

AND

GEORGE OWEN SQUIER, PH.D.,  
First Lieutenant of Artillery, U. S. Army; Instructor Department of  
Electricity and Mines, U. S. Artillery School.

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*(Concluded from vol. cxlv, p. 308.)*

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#### DISCUSSION.

PROF. WILBUR M. STINE [Armour Institute, Chicago]:—  
Responding to your request to contribute to the discussion of the "Squier and Crehore Synchronograph System on the Telegraph Lines of the British Government," I shall briefly discuss the report in connection with the original paper presented to the American Institute of Electrical Engineers, April 21, 1897. Had the authors confined themselves to the strictly electrical engineering aspect of the investigations, the discussion would be scientifically more interesting and profitable. Since they lay more stress on the commercial application of their devices, the discussion is thereby considerably modified. A distinction should be made in the nomenclature of their system. According to their original paper, they worked a synchronous transmitting system in combination with a graphical receiver, of their own design. In the report just presented, the work of the authors is confined chiefly to a system of synchronous transmission of signals.

Their application to the physical principle of the rotation

of the plane of polarized light by a magnetic field of force of coincident lines was a laboratory experiment of great beauty and exceeding simplicity. Such a receiver is practically perfect in that the energy of the magnetic field may suffer rapid oscillations without sensible hysteretic and eddy-current losses. In this way the reactance of the receiver is purely inductive, with a practically constant co-efficient of self-induction, rendering it easy to compensate for the inductance by either distributed or localized capacity to any desired extent. This receiver places in the hands of the investigator a physical apparatus of great value.

The method of photographically registering the light transmitted through the magnetic field is, while satisfactory in the laboratory, of very doubtful applied value. The cost of the photographic plates, the time required for their development and transmission, combine to make a poor showing against the simplicity of the Morse and certain printing receivers. This portion of their device is properly a laboratory method. However, it is to be recognized that a laboratory method, however complicated, may, if commercial conditions favor and require it, be simplified and rendered practicable. At the same time, the train of receiving apparatus is too complicated to compete with a number of successfully-working receiving devices, and, judging from their report, the authors seem to have come to the same conclusion. It is this portion of their investigations which is marked with originality and possesses especial scientific interest.

In considering their system of synchronous transmission, it is apparent that the authors have merely made an application of the well-known and widely-used principles of the alternate current rectifier. Their experiment of operating an alternating current arc lamp taking ten ampères of current, while interesting of itself, shows their method contains nothing essentially new. This, however, is not in criticism of the application with which they have experimented.

The chief difficulty in sending successive signals over a long land or submarine line consists in the character and value of the time-constant of the circuit. Such circuits contain both



distributed capacity and more or less variable inductance. Were it possible to make the time-constant of such circuits exceedingly small, they could be successfully operated at any speed of signal successions with any wave form, either of direct or alternating potential. But in practice the reduction and control of the time-constant is very difficult. This clearly indicates that there must be some particular electromotive-force wave form for maximum speed and sharpness of the signals transmitted, which will operate the circuit with the least possible resonance. Theory and practice both indicate a harmonic sinusoidal wave form, either alternating or pulsating, to fulfill these conditions. The chief merit of this report lies in the recognition and application of this fact.

No circuit-closing device, by reason of variable contact, can operate a line so as to maintain the reactance constant. Such devices are always faulty, and cannot operate a line with maximum speed and clearness.

The method by which the authors secure a rectification of the electromotive force wave is open to some criticism. For high-speed work the adjustment of the commutating strip and contacts must be exact, or the device is worse than a circuit-interrupter. The mechanical difficulties for securing this adjustment must be very great. The least inaccuracy of the perforations or the effect of moisture in the air, in causing unequal variations in the tape, would impair the adjustment. However, it is doubtless possible to provide mechanical corrections for those and other inequalities.

DRS. EDWIN J. HOUSTON AND A. E. KENNELLY:—The results reached by the experiments described in the paper; namely, that the effective speed of transmission with an alternating electromotive force was three times as great as with an electromotive force of the rectangular type, is a most interesting one. The great disparity, however, between the value of the electromotive force in the two cases somewhat invalidates the comparison; for, while the rectangular electromotive force is given as 100 volts, the sinusoidal electromotive force was 215 volts. Assuming the latter to be an effective value, its maximum was 304 volts, or about three times greater than

the rectangular. It is difficult to say how much allowance should be made for such a considerable variation in the electromotive force of transmission, but it would, probably, be quite considerable. Even making all allowances for this discrepancy, however, it seems remarkable that so great an improvement in speed should have been obtained with the sinusoidal electromotive force; for, while an improvement in speed had been predicted, theoretically, for the sinusoidal electromotive force as compared with the rectangular, the improvement expected was, probably, nothing like so great as that which is claimed in these experiments. It is interesting to observe that not only in the long-distance transmission of power, but also in the long-distance transmission of intelligence, the sinusoidal type of alternating electromotive-force wave is superior to more complex waves.

It is to be regretted that, for the purpose of comparison, the average linear insulation and the average linear inductance are not given in this interesting paper for the telegraphic lines on which the tests were conducted. While it may be true that the simple product of capacity and resistance gives, with sufficient accuracy for practical purposes, a numeric whose magnitude is inversely proportional to the speed attained, yet, it is not reasonable to suppose that the inductance and insulation have no effect upon the speed, whatever theory of transmission be adopted; whereas, according to the existing theory in general recognition, they have a very important influence which cannot be neglected when the ratios of inductance to capacity, and of conductor-resistance to insulation-resistance, are relatively so considerable as in the case of overhead telegraph lines.

It will be very interesting to ascertain what results may be found in practice with sinusoidal electromotive forces in transmission over submarine cables, in which the ratio of inductance to capacity and of conductor-resistance to insulation-resistance is relatively so small that the product of capacity and resistance is the true criterion of the slowness of transmission.

As regards the conclusion which the authors draw from the paper, that Government control and operation of the tele-

graph would be a benefit to the people of the United States because such control has proved advantageous in Europe, we think some doubt may be expressed, since the conditions are so different in the two countries. When Government Departments are operated by a personnel independent of political aims and influences, the proposition seems more likely to be worthy of assent.

PROF. R. A. FESSENDEN [Western University of Pennsylvania, Allegheny, Pa.]:—To the very natural gratification with which we learn of the brilliant success of this apparatus when put in competition with the most advanced system of the most advanced country (in this line) in the world, is added the more purely scientific pleasure of witnessing the triumph, at the first test, of a method developed upon sound theoretical principles over one which has had the advantage of years of assiduous experimental work.

What the outcome of the authors' labors may be cannot be at present foreseen. Here we certainly have an apparatus capable of fulfilling all demands upon it. As the writers point out, it can be quadruplexed, and it can also be used with different periodicities. Practically then, the capacity of a single wire may be considered infinite. The question then is, "Who shall put it to work?"

I believe it is a generally understood thing that the great telegraph companies do not want any improved apparatus. I have, at various times during the past ten years, been informed of this by men who were in a position to know, and whom I consulted with reference to improvements in such apparatus. It was stated that improvements would only be purchased when there was danger that they might lead to the formation of a competing company if not purchased. The fact that, though systems of rapid telegraphy have been in use for a long time in Europe, they have not been used to any extent in this country until recent years would seem to give some countenance to these statements.

The plan suggested by the authors, of a Government postal telegraph line, seems to be sufficiently feasible, proper and practical. There is no question of the vast benefit which has

resulted from the taking over of the telegraph by the British Government. Were it not for the ruinously low rate at which press messages are transmitted this system would be in a position to pay large dividends. There is no reason why we should continue to fall behind Europe in such matters.

The reasons for the assumption of such functions by the Government are many. No man can spend his waking hours in the continually enforced contemplation of the principle of the conservation of energy without appreciating the enormous losses which our present methods involve. The chief objection made is, that since we have so much corruption in politics with a given number of offices, we shall have much more if we create more. This always reminds me of Mark Twain's theory of the Mississippi, *i. e.*, that since, in a given number of years, the river had been shortening itself by cutting across bends at the rate of say twenty-miles per year, that in the year 2017, St. Louis would be a suburb of New Orleans. The real trouble at present is that we have not enough corruption, or, to state it more accurately, we do not give enough opportunity for corruption. We do not select our city governors from the beer saloons, because we have an especial admiration for the class, but because we are so well off and can receive so little immediate hurt from bad government that we take no interest in the thing. If the salaries of all employees in New York were fixed by the aldermen, only men of the best moral character would have any chance of election. It is, therefore, both for its direct and indirect benefits that the suggestion of the authors deserves to be carried out.

From the tests described, it is evident that we have now what may be called a perfect transmitter. It is doubtful if we shall ever improve it. The writer feels a slightly personal interest in the matter, as the advantage of using the sine wave in telegraphy was first pointed out by him (*Electrical World*, September 15, 1894). The apparatus mentioned therein (which is mistakenly given there as designed in 1891, as it was not until January, 1892) was, however, only designed for moderate speeds, on account of its mechanical construction, which necessitated the waiting after the key was pressed down for a pin on

a revolving shaft to engage, carry another pin through a definite part of a revolution and release it again, so that, whilst it got over the difficulties for which it was designed, it could never have been used in the manner in which that of the authors of the paper can.

When we have better receiving instruments we may expect even higher speeds with the authors' apparatus. The present instruments for receiving are defective in the following points:

(1) The ohmic resistance of the instrument is often very high. Since, as Heavyside has pointed out, its reactance should equal that of the line, and as it may easily be shown that its resistance should be as nearly zero as possible, its inductive voltage should equal the voltage drop on the line.

(2) At the position of rest, the co-efficient of self-induction should be less than one-fifth of the value when the moving part has made its stroke.

(3) The mark should always be made upon the return and not on the forward stroke, thus regaining all the energy stored up in the spring.

(4) The spring should be fastened on the moving part by a small crank, so that the acceleration of the spring may follow a sine square law. Unless this is done there will be always distortion, and the good effect of the sine wave will be partly nullified.

The sine wave has also a great advantage in the receiver, as well as in the line, as we can, with sine wave, so construct a receiver that there are no inertia losses. There is no doubt but that receivers much more sensitive than the syphon recorder can be devised.

I would join in congratulating the authors in their brilliant success, and hope we may soon see the system in commercial use.

MR. A. V. ABBOTT [Chicago]:—The apparatus and the methods devised by Messrs. Crehore and Squier are certainly exceedingly novel and ingenious. Their experiments would seem to indicate that their apparatus was scientifically entirely feasible. There is but little question, I think, as to the opinion that improved facilities for rapidly transporting intelligence are in demand. There is no doubt but that if all our letters

could be sent by telegraph instead of by the slower process of the mails the community would reap an immense advantage, but there always comes in the commercial question as to whether facilities of this kind will pay, so that it seems to me the real point at issue concerning the synchronograph is the possibility of so simplifying and commercializing its operation as to make it available for the transmission of such matter as now occupies the mail bags of this country.

MR. PATRICK B. DELANY [South Orange, N. J.]:—I have read with much interest the report of Drs. Crehore and Squier relative to the tests of the synchronograph over some telegraph lines in England, in which it is claimed that the speed of the Wheatstone receiver was greatly increased by the use of sinusoidal alternations.

Without knowing what further light the discussion before the Institute may have thrown upon the results stated, I venture a few comments which will, I trust, be considered as subject to any revisionary effect that the discussion may have developed.

In the absence of any adequate specimens or fac-similes of the received record, however, it is hardly worth while to theorize on the cause of an unknown effect. In cable telegraphy, where the syphon recorder is used, there are four recognized degrees of legibility, viz.: "readable," "fair," "good," and "good enough for traffic," and the range between these limits amounts to about 50 per cent. of the speed. The same rule obtains within somewhat narrower limits in all recording systems.

In some of the tests reported, it is stated that certain "frequencies" were reached, and in others "messages were recorded with perfect clearness."

From the report it is difficult to determine whether the "frequencies" were simply rheotomic, and computed for word counting on the basis of thirty-six makes and breaks or half waves per word, or actual words. Pasting pieces of paper on a circuit wheel geared to or mounted directly upon the shaft of the generator can hardly be called telegraphy, or the machine a "synchronograph." It is synchronous in the same sense

that one end of a rigid shaft is synchronous with the other in its revolution. No one will deny that so far as "sparking" is concerned the Wheatstone and all other systems employing air gap contact-breaking devices would be improved if the circuit could always be broken at the time of no current, as it is proposed to accomplish by the synchronograph. This is of little or no consequence, however, where the air gap is dispensed with, and the transmitting tape is drawn between the contact points, as an arc cannot be formed to any injurious extent before it is brushed out by the paper. In fact, sparking is *prevented* in the first place by the burnishing effect of the transmitting tape on contact points meeting in the holes. It does not follow that, because the circuit can be broken at zero by pasting pieces of paper on a wheel mounted on the shaft of the alternator, or by using an endless band a few feet in length, the same degree of accuracy can be reached with various lengths of tape coming from numerous perforating machines having more or less imperfection in spacing. The play necessary for the sprockets of the feed wheel in the perforating machine and the transmitter, the drag put upon the tape by inertia of the roll of paper, or the friction of the contact fingers on the wheel of the transmitter, all combine to prevent synchronism between the perforations and the current waves.

And as any departure from absolute synchronism must result in false signals and the clipping of the regular ones, the difficulties in the way of applying sinusoids in practical telegraphy would seem to be a serious offset to any advantages possessed by the character of the current itself. With the Wheatstone receiver at least, transmission would have to commence from a standstill of the transmitter, it being necessary to begin each message or tape with the same polarity for marking, otherwise the polarized relay of the receiver would be reversed, while with a chemical paper receiver considerable confusion would result in translation unless the same course was followed. The construction of the signals on the receiving tape is a most serious objection, and involves a radical departure from legibility and accuracy. Ignoring the utterly impracticable proposition for the use of a *negative* record, the use

of two dots for a dash in the same line with the regular dots seems to strike at the foundation of efficiency, no matter what advantages sinusoidal currents might have as to speed or distance of working.

The record is the output, and a difficult one offsets all other considerations.

In the trials described in the report, with one exception the difference in speed and current pressure between the Wheatstone and the synchronograph transmitter seems to have been maintained in even ratio, the exception being the trial over the London-Aberdeen loop,  $K R = 261,215$ , in which forty-six words per minute with 100 volts is credited to the Wheatstone transmitter and 135 words per minute to the synchronograph transmitter with Wheatstone receiver at eighty-five volts. A specimen of the record would be especially interesting.

In the London-Aberdeen loop experiment without earth,  $K R = 65,304$ , the report states that "the synchronograph and chemical receiver sent at 'frequency' of 723," but that it was discovered that, with the loop broken at Aberdeen, the signals were received in London just the same. A specimen of this record submitted cannot be considered as the result of actual working over this circuit, but even though the signals had really passed around the loop, they certainly do not mark any advance in speed for simple alternations over a circuit of this kind at 200 volts or over.

As the dots shown in the specimen record are all in one line, it is to be assumed that the reversals were omitted in the arrangement of the pieces of paper on the circuit wheel of the transmitter or were eliminated from the record by using an electrode on top or beneath the chemical paper which left no record, thus recording alternate half waves, which, of course, has a clearing effect between the impulses. As this record claimed for the system was admittedly due to induction between the wires beyond Glasgow, it seems strange that, in a test over the same loop with the synchronograph and Wheatstone receiver, in which it is said 540 words per minute were "sent," this inductive effect is not mentioned. Signals composed altogether of dots could be correctly recorded on the



Wheatstone from inductive effects by simply reversing the relay, while signals might be recorded from leakage without reversal, the same as in the regular way.

It is to be regretted that specimens of the work claimed to have been done are not available, and that definite information regarding the transmitting and receiving apparatus has not been included in the report. It has been generally conceded all along that power transmission could be effected most efficiently by wave alternations, and that, over a circuit balanced to resonance, electro-magnets may be actuated by regular reversals at a higher rate than with currents put on and interrupted at full pressure and at irregular periods; but the application of alternations of regular periodicity to practical be recorded at a higher speed provided the tapes of ordinary telegraphic use can be made as synchronous with the generator as permanently-fastened pieces of paper mounted with mathematical precision on a circuit wheel. But, so far as chemical recording is concerned, even with this arrangement and impracticable character of receiving signals, there is no increase in speed shown.

An important factor affecting the speed results cited in the paper seems to have been overlooked in making comparison between the synchronograph and the Wheatstone systems computed on the basis of thirty-six half waves to the word. The synchronograph transmitter, in combination with the Wheatstone receiver, can only employ *complete* waves or their time equivalents at the receiving end, two in succession for a dash, one for a dot, one for the space between the different elements of a letter, two for separating the letters from each other, and three for spacing the words. The Wheatstone, having solid dashes, imposes no sacrifice of time or impulse for distinguishment of the dash from the dots, utilizing half waves for all spaces between the elements of a letter, one complete wave to space the letters from each other and two complete waves to separate the words.

Taking letter B, — - - , for illustration, the synchronograph dash comprising two dots close together represents four half waves, then a space representing two, the first dot repre-

senting two, space two, second dot two, space two, third dot two, and four for spacing from the next letter, making a total of twenty half waves. The Wheatstone transmitter utilizing half waves for each space and dot with two extra after the last dot requires in all but fourteen half waves for this letter. Using the Continental Code, the synchronograph would employ 456 half waves in the transmission of the alphabet, while the Wheatstone requires but 294. Hence it will be seen that while a greater number of "frequencies" may be sent in a given time by the synchronograph, and some of them recorded, it does not follow that the speed of recording *letters* or *words* is raised in a proportionate degree. Furthermore, the excessive number of impulses necessary for the construction of letters requiring lighter and shorter contacts in order to make the time produces an impression at the receiving end proportionately small and faint, making translation exceedingly hazardous and slow, as is shown in the six letters submitted as a sample record. Compared with the ordinary Wheatstone impression, the difference is very striking.

The specimen record of "frequencies" recorded on chemical paper from synchronograph transmission over the London-Aberdeen loop, with no earth and 200 volts, at the rate of 1,446 alternations per second, was, according to the report, obtained with the loop broken at Aberdeen, which fact should have excluded it as an exhibit of speed rate; and, as already stated, it is hard to understand why the Wheatstone record over the same circuit and under the same conditions could have been free from the same induction effect to which the chemical record is attributed.

The chemical exhibit of "frequencies" shows dots but not from impulses of alternating polarity, the negative currents being omitted, nor is there anything to show whether these dots were the result of every-second half wave or sent at comparatively long intervals, which, with a chemical receiver, would make a great difference in the record. A band of tape having one or two holes and drawn synchronously with the transmitter, or a circuit wheel arranged to send one or two impulses for each revolution would, with the chemical receiver moving suffi-

ciently slow to place these dots side by side, show a record very different from one made from transmission of *all* the impulses or half waves and the chemical tape moving fast enough to show them all plainly. With chemical recording, time plays a most important part. One volt will make a record over a line of 100 miles long if sufficient time is allowed at the receiving end for the weak and slowly-arriving current to have its full effect for electrolytic action between the iron-recording wire and the chemical tape; whereas, if the tape be drawn rapidly, no mark would be made over 100 feet of the same line. It would, therefore, be a mistake to suppose that impulses of short duration sent at intervals to a slowly-moving chemical receiver can be used as a basis for arriving at the speed at which successive or regularly alternating impulses without appreciable time between them can be recorded. In calling attention to this fact, no inference is suggested that this mistake was made, but absence of information as to the method of transmission beyond the paper pieces pasted on the generator wheel warrants this explanation of an effect which may not have been generally understood.

In any event, computation of telegraph speeds on the basis of "frequencies" of alternation having regular periodicity is most misleading. A chemical tape moving with speed necessary to record 723 "frequencies" per second over a circuit having  $K R = 65,304$  would show a "tailing" mark from a single dot three inches in length if 200 volts were used. It is difficult to imagine how sinusoids of irregular time are to overcome this difficulty. The arrangement of signals made necessary by their employment would, I think, greatly aggravate the trouble even over the old style dot-and-dash-all-in-one-line plan. The true remedy lies in the employment of self-induction to reduce the tailing effect, and separation of dots and dashes into different lines, so that what tailing is left may be disregarded.

## ELECTRICAL SECTION.

*Stated Meeting, November 23, 1897.*

### THE BOOSTER SYSTEM AS APPLIED TO ELECTRIC RAILWAYS.

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BY J. LESTER WOODBRIDGE.

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The name "booster," a somewhat significant if not very euphonious term, was coined, I believe, by Mr. Wm. S. Barstow, of the Brooklyn Edison Illuminating Company, who was one of the pioneers, if not the pioneer, in the practical application of this system to electric lighting. The word has gradually come to mean any electro-magnetic generator whose armature is connected in series with a transmission conductor or feeder with the object of compensating for the loss of voltage in that conductor due to the current which it is transmitting. As this loss of voltage or drop is proportional to the current, it is evident that, in order to compensate for it exactly, the voltage of the booster must vary in a similar manner; that is, it must rise and fall with the load. If this variation of load is gradual, or the short period fluctuations small, the booster voltage may be hand regulated. But in railway work, unless the fluctuations are taken by an outlying storage battery or other power plant, this is never the case, and it is found necessary to employ the series-wound booster, or what I have called the compound-series machine, giving the series effect, the voltage of the machine varying automatically with the load.

The typical arrangement of booster is shown in *Fig. 1*, *A* being the positive bus and *B* the negative, which are supplied with electric current by the generators *X* and *Y*. *Z* is the booster, connected at its negative terminal to the positive bus, and at its positive terminal to the feeder whose voltage is to be raised. This feeder supplies the distant section of the line *C E*, being tapped into it near its middle point at *D*, whence it feeds in both directions.

The nearer section of the line *A C* is fed directly from the

bus bars, and it is usual, though not always necessary, to insulate these two sections from each other by the section insulator *C*. If this is omitted, there might be danger of overloading the booster. In fact, the path *F D C G* would apparently constitute a short circuit, but its resistance is generally too great to allow the machine to build up without a load on the line. Where it is practicable to do so, it is a good plan to omit this section insulator. This will tend to steady the load on the booster and the voltage at *D*.

The aim is, of course, to maintain the point *D* at station voltage. For several reasons, which will be noted hereafter, this cannot always be accomplished exactly. The voltage here is liable to fluctuate, but the fluctuations can be brought within allowable limits by properly designing the installation, and the average voltage can be brought to that of the bus bars.

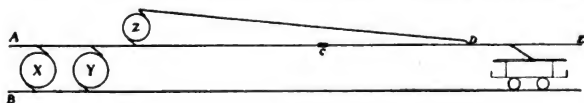


FIG. 1.

The effect, therefore, is about the same as if there were another power-house, rather poorly regulated, situated at *D*.

In *Fig. 2* I have shown the connections of what I have alluded to as a compound-series booster. This is simply an ordinary compound-wound constant-potential machine, connected up so as to get the series effect from both the series and the shunt windings. If the connections in this diagram be followed out, it will be seen that when the double-throw booster switch is thrown down the machine is connected up as an ordinary generator. When it is thrown up, and the machine is in use as a booster, the entire current of the boosted section passes from the positive bus bar through the armature and the series winding; and the shunt coils are connected in parallel with each other and with a certain portion of the feeder, so that a small but constant percentage of the current is diverted through them and their magnetizing force like that of the series winding is proportional to the load. Such an arrangement permits of the use of a regular railway generator as

a booster when required, while at other times it may still be employed as a generator.

The booster system is one of several remedies available for the treatment of the aggravated cases of low line voltage with which nearly every electric road has had to contend at one time or another.

The first and most obvious remedy for such cases is more copper. But, as the distance of transmission is gradually ex-

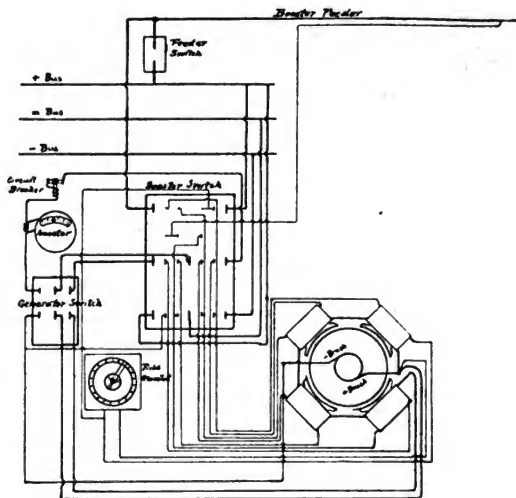


FIG 2.

tended, the cost of copper necessary to carry the maximum current becomes a very serious item, increasing, as it does, with the square of the distance, and even more rapidly as soon as the track drop becomes appreciable, until finally this feeder cost becomes so great that some other solution is sought. For this question of transmission loss must be considered from two quite different aspects, first, that of economy; second, that of practical operation. The first deals with average conditions, the second with maximum conditions. Considerations

of economy dictate that when a feeder system is so proportioned that the cost of the energy loss in every section of it, for a year, say, is equal to the interest on the copper investment for that section for the same length of time, the most economical arrangement has been reached, and it will not pay to add more copper.

This reduces to the law that for best economy the average drop in volts per mile of conductor should be the same throughout the entire system regardless of distance. But from the standpoint of practical operation we know that, regardless of economy, we must maintain the voltage on all parts of the system above a certain minimum under the worst conditions of load. This consideration not only leads to a different distribution of copper from that just given, but, where the load reaches occasionally a maximum many times its average value, or where the distance of transmission is great, we must either install far more copper than economy would prescribe or do something else to maintain the voltage. In fact, most railway managers, without calculating the dividing line exactly, have come to realize in a general way that it will not pay to put up the amount of copper necessary to carry satisfactorily the occasional emergency loads which they are called upon to provide for. An additional power-house is sometimes the solution, though in most cases this is out of the question, and the tendency in general is rather toward concentration of plant. In the great majority of cases, the booster system will be found to meet the requirements exactly, especially when machinery already on hand can be utilized, as has been the case in the installations with which I have been personally connected.

Deferring the consideration of economy for the present, I will first take up a few points on the question of operation. From this standpoint the object of the booster is to maintain station voltage, as nearly as possible, at a distant point on the line. This, as I have intimated above, cannot be done exactly, the variations being due to the following causes, inherent in the booster machine, viz.:

- (1) Saturation of the field magnets.
- (2) Sluggishness, due to inductance and Foucault currents.
- (3) Hysteresis.

The manner in which the first of these would interfere is very evident. If the resistance of the circuit is one ohm, the booster should give 100 volts under a load of 100 ampères and 200 volts under a load of 200 ampères, etc., whereas it will not do this exactly, but if, at 200 ampères, the fields have begun to be saturated, the voltage will be somewhat less than 200. In designing a new machine, this deviation can be reduced within almost any assignable limits by putting plenty of iron in the magnetic circuit. In utilizing a machine already on hand, however, we must either limit the load or provide sufficient copper in the feeder to limit the maximum voltage required, and, therefore, the range of magnetization. That is, if when the machine is built up, say to 300 volts, the saturation curve begins to deviate as far as is permissible from a straight line, we must limit the product of the feeder resistance by the maximum ampères to this amount, 300. The deviation due to this cause can be averaged over the whole range of load by making the machine build up under light loads a little higher than necessary, so that under the heavy loads it will not fall off so much, and, as a considerable range of voltage is not objectionable in railway work, this variation can readily be brought within permissible limits.

The effects of sluggishness due to Foucault currents and to the high inductance of the shunt fields, when these are used, are rather more serious. While the drop in the line responds instantly to changes of current, the changes in the voltage of the machine are more or less gradual. When the shunt fields are connected in parallel with a certain portion of the feeder, it requires an appreciable time for the current in them to rise to the full strength corresponding to an increase in the current in the feeder; moreover, the eddy currents set up in the iron by reason of a change in magnetism tend to retard such change. Lamination of the field cores largely eliminates the latter effect, while the former may be limited by limiting the extent to which the shunt fields are utilized. If they give but a small proportion of the magnetizing force, it will be only that portion that will lag. Their inductance, too, is reduced by dividing the whole shunt winding into as many sections as pos-



sible, and connecting these in parallel with each other when boosting.

As a result of this sluggishness of the booster, we find that whenever the load suddenly drops the voltage on the line will jump above the normal and then fall back, the high voltage of the machine persisting for an instant after the drop in the line has disappeared. Conversely, when the load is thrown on suddenly, the voltage first drops because the drop in the line is first felt, and then rises to the normal again as the machine builds up.

The effects of hysteresis are very similar to those just described, but are of little importance in railway work, owing to the peculiar nature of the variations of load. The booster will, of course, show a higher voltage with a falling load than with a rising load of the same amount, and this difference will often amount to fifty or seven-fifty volts. But a moment's consideration will reveal the fact that in railway work we are almost invariably dealing with a falling load, and can, therefore, figure on the upper curve of the hysteresis loop. For when the current used on any car is shut off it is usually shut off entirely, which would mean a falling load on the booster; and when the current is turned on or increased by the controller it rises instantly to a maximum, and at once begins to fall off as the speed of the car increases, and again we have a falling load on the booster. It is only when a car passes from a lighter to a heavier ascending grade without any accompanying change of the controller that the condition of rising load exists, and this only until its controller or that of some other car on the line is changed. So the curve of rising magnetization can be practically ignored.

In illustration of the foregoing points I have prepared a few diagrams giving the results of voltage readings taken on some of the boosted lines with whose installation I have been personally connected.

*Fig. 3*, drawn from memory, gives an approximate idea of the map of one of these lines, and is worthy of a moment's comment, as the arrangement differs from the typical one shown in *Fig. 1*, in that the booster feeder was bifurcated at *B*. It will

be noted that these two branches,  $BC$  and  $BD$ , are comparatively short, and this is about as far as it is practicable to carry the attempt to boost two lines with one machine. In order that the voltage at the points  $C$  and  $D$  should be maintained as nearly as possible the same in spite of any unequal distribution of load, they were connected not only by the trolley wires but by heavy feed wire. The booster feeder is in two parts all the way back to the power-house, so that by means of a switch at  $K$  and another on the switchboard either line can be disconnected from the booster and fed directly from the bus bar while

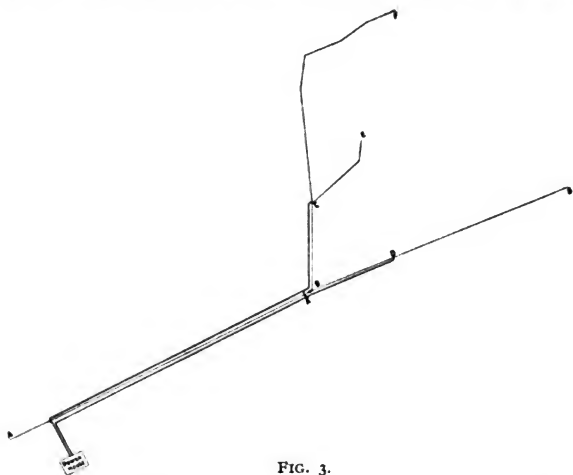


FIG. 3.

the other is boosted, the voltage ratio of the booster (*i. e.*, the ratio of volts to ampères) being at the same time increased to correspond with the increased feeder resistance by means of the rheostat in the shunt-field circuit.

On a day of extremely heavy traffic, voltage readings were taken at the point  $F$  eight miles from the power-house, and I have incorporated a series of these readings in *Fig. 4*. The machine used in this case is a G. E. 500 K. W. four-pole belt-driven generator, and is only moderately sensitive to

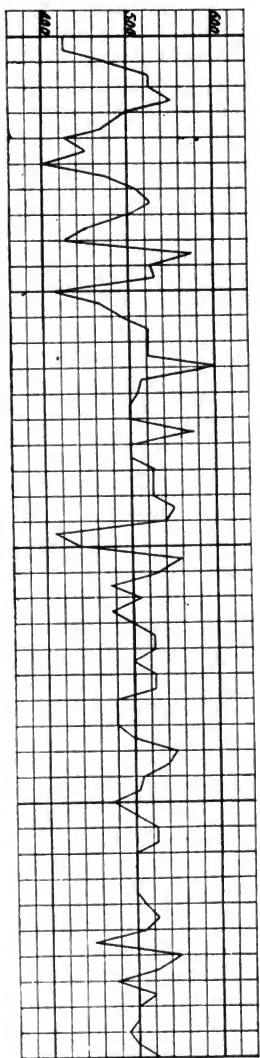


FIG. 4.

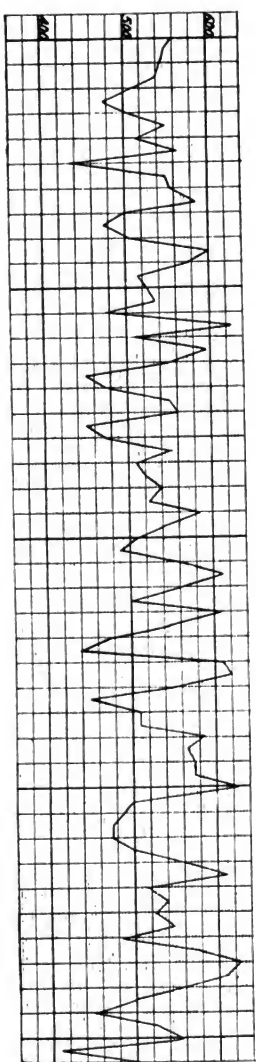


FIG. 5.

changes of load, giving considerable variations in voltage on this account, though not great enough to be objectionable.

*Fig. 5* shows similar readings taken in another case, where all the causes of voltage variation were particularly aggravated. Here the system was installed in order to dispense with a small power-house six miles from the main plant. The machine used is a G. E. 300 K. W. four-pole belt-driven generator, and is unusually sluggish. Moreover, these readings were taken before the entire necessary amount of wire had been put up for the booster feeder, and the machine had to be built up for the time being in a higher ratio than was planned for, so that the effects of saturation are evident.

*Fig. 6* shows readings taken on a line boosted with a Westinghouse 200 K. W. six-pole generator, belt driven. This machine builds up in the ratio of 170 volts to 100 ampères, the resistance of the circuit being 1.7 ohms, an unusually high figure, and, were it not for the fact that the machine is remarkably sensitive, these variations of voltage would be excessive. In fact, the deviations that appear on this diagram are caused not by Foucault currents but by the inductance of the shunt fields, which, in this case, supply nearly half of the total magnetizing force. The power-house voltage was about 525, and the booster would at times add over 400 volts to this.

*Fig. 7* shows the operation of the same machine on another line when the resistance of the circuit was but one ohm, and only the series winding of the machine was used. This shows remarkably steady voltage, considering the fact that at times the station pressure was raised by the booster to a total of 850 volts, the drop on the line at such times being about 350 volts.

These diagrams give a fair idea of what can be done with an ordinary railway generator, without altering the machine in any way. In each of these cases the machine could be used as a 500-volt constant-potential generator when desired by throwing the booster switch.

We come now to the other aspect of the booster question, namely, economy. This might appear at first sight the most important consideration, but I think we shall find that it really does not enter into the question of "booster or no booster"

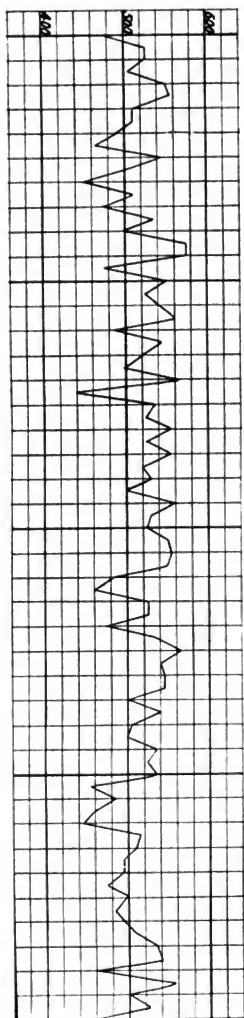


FIG. 6.

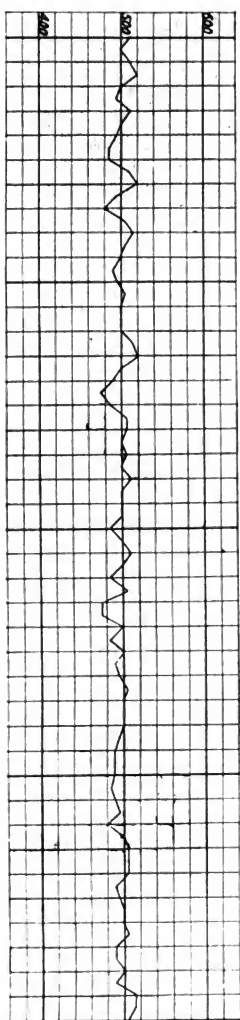


FIG. 7.

to so great an extent as might at first be supposed. The law of transmission efficiency already mentioned, viz.: that the cost of the  $C^2 R$  loss in conductors should in the long run equal the interest on the copper investment obviously makes the determination of sizes of conductors, from the standpoint of economy, independent of voltage, for any given output in ampères. In other words, whether we boost or not we should, for economy, put up a certain size of feeder to transmit a certain load in ampères. Having done this, having reached the point where additional copper will cost more in interest than it will save in power, the question of boosting is almost wholly one of practical operation, for it will not materially alter the economic size of conductors. If the voltage is still too low at times for satisfactory service, it will pay to boost at those times rather than put up more copper. To be sure, the booster installation costs something, but where machinery already on hand can be used, as is usually the case, the cost becomes comparatively nominal. The efficiency of the booster unit will also probably be less than that of the rest of the plant, owing to the fact that it will have a more variable load, averaging considerably below its full capacity. But these points are usually more than offset by the increased efficiency of the motors when operated at higher voltage, and by the decrease in the current required to transmit a given power at higher potential, and the corresponding decrease in line loss. Then, too, it is as a rule not advisable to plan to operate the booster continually or even frequently, but to put up enough copper to carry the ordinary loads satisfactorily, reserving the booster for times of excessive traffic. But the lower the price of fuel the more extensively can the booster system be used with economy, and one case has come under my observation where it has proven economical to run the booster all day and every day in the year. In this case fuel costs 60 cents per ton, and I estimate the cost of operating the booster eighteen hours a day at about \$196 per year, while the interest on the cost of the booster feeder would be \$216 per year. So it evidently would not pay to put up more wire on that line.

When the booster is used only a few times a month, and

then for only a few hours, as is usually the case, the question of economy is so obviously unimportant that it is hardly worth while to reduce it to exact figures, except as a matter of curiosity.

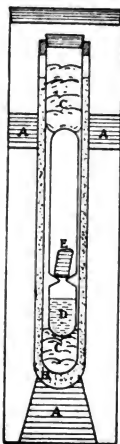
## CHEMICAL SECTION.

*Stated Meeting, Friday, March 15, 1898.*

### ON A SUPPOSED CHANGE OF WEIGHT WITH CHANGE OF TEMPERATURE.

BY PAUL R. HEVL, Member of the Institute.

Certain experiments performed by the writer during the past summer seemed to indicate that the loss of weight noticed in weighing hot bodies was not entirely to be accounted for by the rarefaction of the surrounding air, but that there might be a true loss of weight of minute proportions. To settle this point, the following apparatus was devised, a sectional view of which is shown in the accompanying cut:



The outer case consisted of a flat-bottomed glass cylinder made from a piece of tubing. It was 4.5 centimeters in diameter and 17 centimeters high. Within this was supported, by pieces of cork, *A*, a jacket made from two test tubes. The diameter of the larger tubes was 2 centimeters, and the space between the walls of the jacket about 2.5 millimeters. The jacket was 1.4 centimeters high over all. The space between the walls contained glacial acetic acid, *B*, and the test tubes were held together by a ring of cork between them at the mouth, which ring was cemented air-tight by a mixture of rosin and beeswax. The jacket with its contents could be lifted out of its cork supports whenever desired.

A little bomb for generating heat was constructed as follows: A piece of glass tubing of such diameter as to slip easily inside the jacket was choked by heating and pressing upon a three-cornered file. By this means the bore of the tube was

sharply reduced at one point to a slit about 2 millimeters wide. The choked tube was sealed off about 1.5 centimeters below the choke, and in the lower chamber thus formed was placed dilute sulphuric acid, *D* (half water by volume). Holding the tube upright, a lump of caustic potassa, *E*, was dropped in, which was arrested at the choke. Still keeping the tube upright, it was sealed off some 2 or 3 centimeters above the potash.

The acetic acid in the jacket was now frozen. This substance when pure is said to freeze at  $16.7^{\circ}$  C., but I have never been able to obtain any of a higher melting point than  $15^{\circ}$  C. It exhibits surfusion to an excessive degree, so that to start the solidification it is necessary to use a mixture of ice and salt. Solidification once started can be completed by a stream of cold water. The melting point of the acid is not far below the usual temperature of a room, and the jacket is not directly exposed, but protected in the packing case by an air-jacket about 1 centimeter thick, so that the solid acid can be kept for some time.

The prepared bomb was dropped within the acetic acid jacket, a little cotton, *C*, being placed beneath and above the bomb. The opening of the inner test tube was corked, and the mouth of the outer packing case closed by a flat cork, whose pores had been stopped with paraffin, and which was cemented into the mouth of the tube by means of paraffin, so as to be air-tight for a moderate increase of pressure.

The apparatus thus prepared was counterpoised upon a balance, and when equilibrium was attained the beam was lowered and the pan arrests set. The apparatus was now grasped through a handkerchief, removed from the pan, held inverted a second, and then replaced in its former position. The beam was again raised, the pan arrests released, and the swinging of the pointer noticed.

In all cases some trifling displacement of the zero point was observed, but so small as to be far less than the limit to which the balance could be trusted with the great load of the apparatus (140 grams) upon it. With this load the balance used could not be trusted to give concordant weighings beyond the third decimal place.

The result is entirely negative, but is of value in so far as it



enables us to assign by direct experiment a superior limit to any change of weight due to change of temperature. It might be interesting to repeat this experiment with a balance sufficiently large and delicate to carry the weighings a couple of decimal places further. It seems hardly credible that if gravitation is a property of matter it should be unaffected by the state of the matter. The first step towards an explanation of gravitation will have been made when it shall be shown that gravitation depends even in the slightest degree upon something else than the relative positions of bodies.

## THE ZEUNER DIAGRAM.

BY WILLIAM FOX,

Assistant Professor of Applied Mathematics.

Professor Peabody, in his book on valve gears, makes the following statement: "Zeuner's diagram does not admit of the use of the lead in solving problems that arise in designing valves, but we may use instead the lead-angle." (Page 16.) Professor Spangler, on the other hand, states, on page 157 of his book, that no other diagram "is as convenient as and none more accurate than the Zeuner diagram." As a matter of fact, he solves Problem IV, involving lead, *exactly* by means of the Zeuner diagram, and only *approximately* ("by trial") by means of Bilgram's method.

In order to prove that there are no problems incapable of an exact geometrical solution by means of the Zeuner diagram, we shall first enumerate all the problems possible.

Let  $r$  = eccentricity =  $C E$  (*vide*. Fig. 1).

$l$  = lap (outside) =  $C P$ .

$l'$  = exhaust lap (inside).

$p$  = port-opening (maximum) =  $P E$ .

$i$  = lead =  $A L$ .

$i'$  = exhaust lead.

$\beta$  =  $90^\circ$  — advance angle =  $E C L$ .

$\alpha$  = angle whose versine is ratio of cut-off =  $K C L$ .

$\alpha'$  = exhaust cut-off angle (compression or cushion).

$\gamma$  = lead-angle (pre-admission) =  $L C M$ .

$\eta'$  = exhaust-lead-angle (release).

There will be two sets of problems, one set involving the quantities  $r, p, l, i, \beta, a, \eta$ , and the other set, the quantities  $r, l', i', \beta, a', \eta'$ . If we solve only one of these sets of problems, the others can of course also be solved in the same manner.

We have, from the diagram, the following equations:

$$p = r - l \quad (1)$$

$$r \cos. \beta - l = i \quad (2)$$

$$r \cos. (a - \beta) = l \quad (3)$$

$$\beta = \frac{1}{2} (a - \eta) \quad (4)$$

These equations involve seven (7) quantities; hence if any three quantities are given the other four may be found. The only exceptions are the data  $r, p$ , and  $l$ , and the data  $\beta, a, \eta$ , from which it is evident no other quantities can be found.

Making the required combinations of three quantities, we obtain the following problems:

Problem (1) given  $r, l, \beta$ , to find the others.

(2) given  $r, l, a$ , to find the others.

(3) given  $r, l, i$ , to find the others.

(4) given  $r, l, \eta$ , to find the others.

(5) given  $r, i, \beta$ , to find the others.

(6) given  $r, i, a$ , to find the others.

(7) given  $r, i, \eta$ , to find the others.

(8) given  $r$  and any two of  $a, \beta, \eta$ , to find the others.

(9) given  $l, i, a$ , to find the others.

(10) given  $l, i, \beta$ , to find the others.

(11) given  $l, i, \eta$ , to find the others.

(12) given  $l$  and any two of  $a, \beta, \eta$ , to find the others.

(13) given  $i$  and any two of  $a, \beta, \eta$ , to find the others.

(14) given  $p, i, \beta$ , to find the others.

(15) given  $p, i, a$ , to find the others.

(16) given  $p, i, \eta$ , to find the others.

(17) given  $p$  and any two of  $a, \beta, \eta$ , to find the others.

We omit problems involving  $p$  and  $l$ , or  $p$  and  $r$ , as they are identically with data  $r$  and  $l$  (Problems 1 to 4).

### SOLUTIONS.

*Problem 1.*—The construction gives at once (*vide Fig. 1*) the points  $A, B, P, E, L, D$ , and the solution is evident.

*Problem 2.*—Given points  $C$ ,  $B$  and circle  $XX$  through  $K$  with radius  $r$ . A line through  $B$ , perpendicular to  $BC$ , will intersect the circle  $XX$  in point  $E$ .

*Problem 3.*—Given points  $C$ ,  $A$ , and  $L$  and circle  $XX$ . A line through  $L$ , perpendicular to  $CL$ , intersects the circle  $XX$  in point  $E$ . The circle  $CBE D$  (diameter  $= CE = r$ ) gives the other important points.

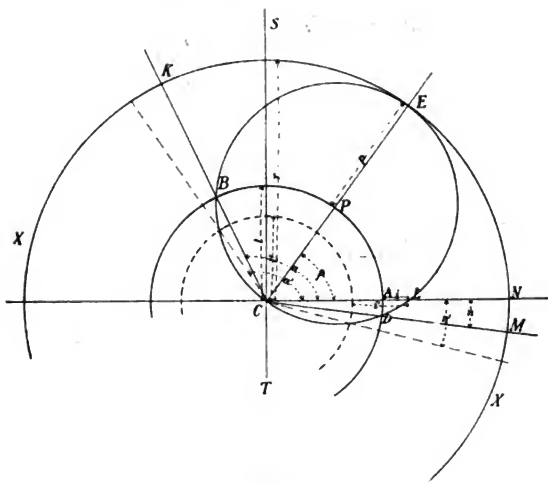


FIG. 1.

*Problem 4.*—Given points  $C$ ,  $A$ , and  $D$  and circle  $XX$ . To find  $E$ , we must draw through point  $D$  a line perpendicular to  $CD$ , intersecting circle  $XX$  in point  $E$ .

*Problem 5.*—Given points  $C, E$ . The circle on  $CE$  as diameter cuts the line  $CN$  in point  $L$ . Measuring off distance  $i = AL$ , gives point  $A$  and consequently the lap circle.

*Problem 6.*—This is one of the problems involving the lead  $i$ , and is somewhat more difficult of solution, because we have

to combine equations (2) and (3) and eliminate  $\beta$ , in order to find the value of  $l$  in terms of  $r$ ,  $i$ , and  $\alpha$ .

Given (*vide Fig. 2*) point  $C$ , circle  $XX$ , and points  $K$  and  $N$ . Draw the line  $ST$  perpendicular to  $CN$ ; project the point  $K$  on line  $ST$  giving point  $Q$ ; bisect the angle  $\alpha$  ( $KCN$ ) by the line  $CR$ ; lay off  $CI = i$  (lead) below  $C$  if  $i$  is positive or above if the lead is negative; through  $I$  draw a line parallel to  $CR$  and cutting a circle, radius  $CO$  and centre  $C$ , in the point

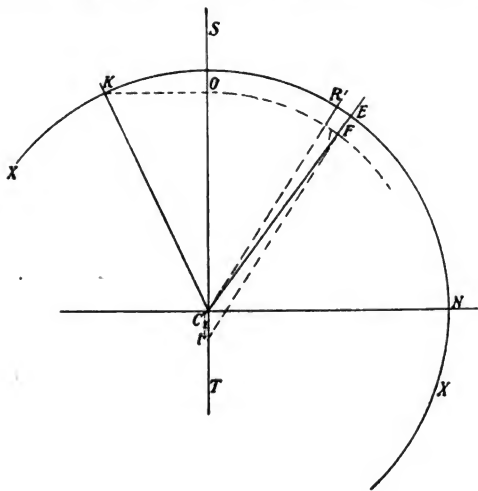


FIG. 2.

$F$ . Then will the line  $CF$  produced pass through point  $E$ , thus giving the angle  $ECN = \beta$ .

Proof:  $CO = CF = r \sin. \alpha$

$$\angle CIF = \angle OCR = 90^\circ - \frac{\alpha}{2}$$

In the triangle  $CIF$ ,

$$\frac{CI}{CF} = \frac{\sin. CFI}{\sin. CIF} = \frac{\sin. FCR}{\sin. (90^\circ - \frac{\alpha}{2})} = \frac{\sin. FCR}{\cos. \frac{\alpha}{2}}$$

or, 
$$\frac{i}{r \sin. a} = \frac{\sin. F C R}{\cos. \frac{a}{2}}$$

or, 
$$i = r \sin. F C R \frac{\sin. a}{\cos. \frac{a}{2}} = r \sin. F C R \frac{2 \sin. \frac{a}{2} \cos. \frac{a}{2}}{\cos. \frac{a}{2}}$$

$$= 2 r \sin. F C R \sin. \frac{a}{2}$$

$$= r \left\{ \cos. \left( \frac{a}{2} - F C R \right) - \cos. \left( \frac{a}{2} + F C R \right) \right\}$$

$$= r (\cos. F C N - \cos. F C K)$$

$$= r \cos. F C N - r \cos. (a - F C N)$$

This equation is identical with the following derived by combining equations (2) and (3):

$$r \cos. \beta - r \cos. (a - \beta) = i \quad (5)$$

Hence,  $\angle F C N = \beta$

Problem 7.—Combining equations (4) and (5) we get

$$r \cos. \beta - r \cos. (\beta + \eta) = i \quad (6)$$

or 
$$r \cos. \left( \beta + \frac{\eta}{2} - \frac{\eta}{2} \right) - r \cos. \left( \beta + \frac{\eta}{2} + \frac{\eta}{2} \right) = i$$

whence 
$$i = 2 r \sin. \left( \beta + \frac{\eta}{2} \right) \sin. \frac{\eta}{2}$$

now 
$$\sin. \eta = 2 \sin. \frac{\eta}{2} \cos. \frac{\eta}{2}$$

or 
$$2 \sin. \frac{\eta}{2} = \frac{\sin. \eta}{\cos. \frac{\eta}{2}}$$

hence 
$$i = \frac{r \sin. \left( \beta + \frac{\eta}{2} \right) \sin. \eta}{\cos. \frac{\eta}{2}}$$

or 
$$\frac{i}{r \sin. \eta} = \frac{\sin. \left( \beta + \frac{\eta}{2} \right)}{\left( \sin. 90^\circ - \frac{\eta}{2} \right)} \quad (7)$$

From this we readily get a solution similar to that of Problem 6.

Given (Fig. 3) point  $C$ , circle  $XX$ , and points  $N$  and  $M$ . Draw  $ST$  perpendicular to  $CN$  and project point  $M$  perpendicularly on  $ST$  to point  $Q$ . Bisect the angle  $\eta (= MCN)$  by the line  $CR'$ . Lay off  $CI' = i$  (lead) on  $CS$ , and through point  $I'$  draw a line parallel to  $CR'$  and cutting a circle, radius  $CQ$ , centre  $C$ , in the point  $F'$ . Then will the line  $CF'$  produced intersect the circle  $XX$  in point  $E$ , making the angle  $ECN = \beta$ .

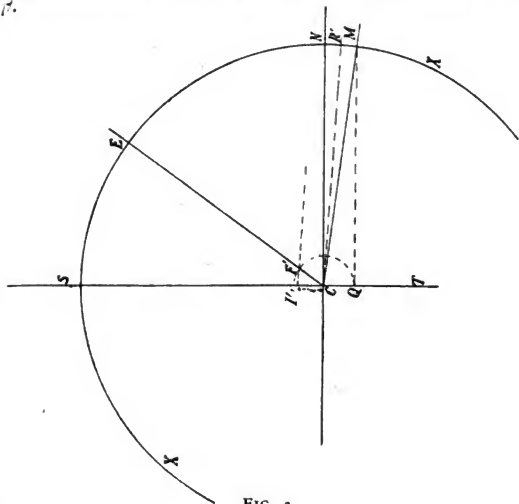


FIG. 3.

From the triangle  $CI'F'$

$$\frac{CI'}{CF'} = \frac{\sin. CF'I'}{\sin. CI'F'} = \frac{\sin. CF'I'}{\sin. QCR'}$$

or

$$\frac{i}{r \sin. \eta} = \frac{\sin. CF'I'}{\sin. \left(90^\circ - \frac{\eta}{2}\right)}$$

This is identical with equation (7), and, therefore,

$$\angle CF'I' = \beta + \frac{\eta}{2} \text{ and } \beta = CF'I' - \frac{\eta}{2} = F'CR' - \frac{\eta}{2} \\ = F'CN$$

Problem 8.—Given points  $C$ ,  $N$  and circle  $XX$  around

center  $C$ . Any two of the points  $M$ ,  $E$ , and  $K$  being given, the third one is found immediately by observing (Eq. 4) that  $ME = EK$ .

The circle  $CBE L D$  being drawn on  $r = CE$  as a diameter, the points of intersection with the given lines  $CM$  and  $CN$ , and  $CK$  will give the other quantities required. (Fig. 1.)

*Problem 9.*—Given (Fig. 1) point  $C$  and lap circle and line  $CB$  giving point  $B$ ; also distance  $AL = i$  gives point  $L$ . At  $L$  erect a perpendicular to the line  $CL$ , and at  $B$  a perpendicular to the line  $CB$ . The intersection of these perpendiculars will be the point  $E$ .

[To be concluded.]

#### ANNUAL REPORT OF THE DIRECTOR OF THE DRAWING SCHOOL OF THE FRANKLIN INSTITUTE, FOR THE SESSIONS 1897-1898.

The number of pupils this year has been just about the same as last, which, considering the generally disordered condition of the building due to the alterations, is as good as could be expected. The regularity of attendance has been very good, and there were few who did not maintain their interest and industry to the end. The Architectural Class has been particularly enthusiastic. Almost the entire school has been composed of young men actually engaged in work or business, where a knowledge of drawing is requisite, or at least desirable, and, consequently, there has been very little idleness or trifling, but a persistent effort to make the most of the opportunity. This is very commendable, because it is not recreation, but work, and work under disadvantages. Daylight is none too good for first-class drawing, and artificial light is at best very trying for fine and accurate work, and when this work must be done in hours supposed to be devoted to rest or pleasure, it is rather surprising that more do not fall out of line early in the season.

The utility and importance of the study for all those engaged in mechanical industries is the secret, and it speaks well for our industrial future that so many young men are willing to devote two evenings of every week to their improvement of their technical knowledge.

It is gradually being realized by industrial concerns that thoroughly detailed drawings, with everything well thought out as to materials, finish and special characteristics, not only greatly expedite work but also reduce its cost. Perfect clearness and certainty of the meaning of drawings require a higher grade of ability to produce and cost more money, which, however, is sure to prove a good investment.

Every hour spent in the drawing office on the design, dimensions and classifications of the details, is worth three in the shop, if they have to be looked up there. And these things, when properly recorded on the drawings, are done for all time, while if left to the foreman and mechanics, they have to be repeated every time the work is done. But to become capable of doing them well the draughtsman must get all the shop experience possible, by

actual work if he can, or by observation if he must. Much of the hustle and bluster seen in many shops is due to the fact that many men are required to attend to things outside their province, which have been neglected by the draughtsmen.

The purpose of this school is to give a start in the right direction to the pupils, in order that they may eventually acquire the ability to fill this need, and this purpose has been kept steadfastly in view, and will so continue.

WM. H. THORNE, *Director*.

THE FOLLOWING STUDENTS ARE ENTITLED TO HONORABLE MENTION :

*In the Senior Mechanical Class.*

Louis Snyder,	Carl A. Dannerth,
George W. J. Stout,	Adam Frazer,
Harry V. Walker.	

*In the Intermediate Mechanical Class.*

H. C. Brinton,	Alexander Stevenson,
Charles P. Richter,	Joseph Bourgeois.

*In the Junior Mechanical Class.*

Kotaro Omakato,	R. Patterson,
William Bucher.	

*In the Architectural Class.*

John H. Lippincott, Jr.,	Charles Ritzel,
George Smith,	J. A. Kirkpatrick.

*In the Free-Hand Class.*

Charles T. Greene,	George F. L. Linderman,
Robert F. Plum.	

The following students are awarded SCHOLARSHIPS from the B. H. Bartol fund, entitling them to tickets for the next term :

Fritz H. Larson,	Harry Thompson,
John Kleisch,	George Eiselé,
Alfred Whitney, Jr.	

The following students, having attended a full course of four terms, with satisfactory results, are awarded CERTIFICATES :

George H. Bardsley,	Joseph McGovern,
Benjamin Bramin,	Berthold Reibrich,
Adolph K. Bottke,	Warren W. Rice,
Carl A. Dannerth,	Ivan Schultz,
George Eiselé,	Louis F. Snyder,
Howard Fryling,	Russell Stapler,
William M. H. Jones,	Rupert Tricker,
James Keating,	Harry V. Walker,
Henry Wolf.	

And from the Branch School :

Alva H. Bewley,	Jesse H. Weiss,	Harry Robson.
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## NOTES AND COMMENTS.

## REMOVING RUST FROM IRON ELECTRICALLY.

A simple and effective way of clearing rusted iron articles, no matter how badly they are rusted, consists, according to Carl Hering, in attaching a piece of ordinary zinc to the articles and then letting them lie in water to which a little sulphuric acid is added. They should be left immersed for several days, or a week, until the rust has entirely disappeared, the time depending on how deeply they were rusted. If there is much rust a little sulphuric acid should be added occasionally. The essential part of the process is that the zinc must be in good electrical contact with the iron; a good way is to twist an iron wire tightly around the object and connect this with the zinc, for which a remnant of a battery zinc is suitable, as it has a binding-post. Besides the simplicity of this process, it has the great advantage that the iron itself is not attacked in the least as long as the zinc is in good electrical contact with it. When there is only a little rust a galvanized iron wire wrapped around the object will take the place of the zinc, provided the acid is not too strong. The articles will come out a dark gray or black color, and should then be washed thoroughly and oiled. The method is specially applicable to objects with sharp corners or edges, or to files and other articles on which buffing wheels ought not to be used. The rusted iron and the zinc make a short-circuited battery, the action of which reduces the rust back to iron, this action continuing as long as any rust is left.—*Electrical World*.

## DEATHLY ELECTRIC SHOCK.

The cause of death by electric shocks has been experimentally investigated by Prof. T. Oliver and Dr. R. A. Bolam, who describe their methods and results in the *British Medical Journal*. The increasing employment of electricity within the last few years has demonstrated, by the accidents to workmen engaged in its generation and distribution, that danger is involved. Two opinions are held as to the cause of death in such cases, viz.: (1) that death is due to failure of the respiratory center (d'Arsonval); (2) that it is due to sudden arrest of the heart's action. From the appearance presented by the internal organs after death, some physiologists have maintained that death is due to asphyxia. But other evidence suggests that death is not due to failure of the respiratory center. In the experiments carried out by Professor Oliver and Dr. Bolam, an alternating current was used, and death appears to have resulted from heart, rather than respiratory, failure. Whilst in some of the experiments death seemed to be due to contemporaneous cessation of the respiration and heart's action, yet in most there was ample demonstration that the organ first to be arrested was the heart, for breathing was observed to continue rhythmically for a brief period, and then irregularly and feebly before stopping. There is reason to believe that only in the case of very high voltages with currents considerably above the potential usually required to kill the animal is there simultaneous stoppage of heart and respiration. Primary cessation of the heart's beat is, without doubt, the general rule, while

under no circumstances did the authors succeed in causing primary arrest of respiration followed by failure of the heart. It follows from this that resuscitation in apparent death from electric shock is made much more difficult than if the result was brought about by respiratory failure. With reference to these experiments, Dr. Lewis Jones calls attention, in the *Electrical Review*, to a similar investigation carried out by him in 1895, using a continuous current.—*London Nature*.

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### THE THIRD-RAIL SYSTEM IN THE SNOW.

The great snow storm of January 31, 1898, which raged over New England, has proved that a railroad can be operated by the third-rail electric system under the most adverse conditions. That portion of the New York, New Haven and Hartford Railroad, between New Britain and Hartford, operated by electricity, was kept open during the whole of that day, and the trains were run with but a few seconds delay in the schedule, while the steam trains on the main lines were held up and delayed for three or four hours.

A heavy snow storm had long been desired by the electrical engineers and railroad officials in order that as severe a test as possible might be applied to the third-rail system. It has been a question whether, with the third rail practically surrounded by snow and moisture, the current leakage would seriously affect the operation of the motors on the cars. This question was settled by the snow storm. There was absolutely no leakage, and, once the heaviest part of the snowfall was removed by the snowplows, no interruption in the motor-car service occurred.

Col. N. H. Heft, chief electrical engineer of the New York, New Haven and Hartford Railroad, and the engineers of the General Electric Company, express great satisfaction at the performance of the entire system under the severe climatic conditions.—*Electrical World*.

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### BOOK NOTICE.

*Elementary Form*, or outlines of concrete geometry. A key to the sequence of figure. By the Rev. W. F. C. Morsell, Springfield, Mass. Milton Bradley Co., 1897. (Price, Manual and blocks, \$5.00; Manual alone, \$1.00).

The author has elaborated what appears to be a philosophical method of studying the relationships of elementary geometrical forms and of their composites. The text is devoted to the exposition of the system and is intended to be illustrated and explained in concrete form with the aid of a set of blocks invented by the author.

The system devised by Mr. Morsell is quite original and should prove very helpful to teachers and pupils in simplifying the study of applied mathematics.

W.

## Franklin Institute.

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[*Proceedings of the stated meeting held Wednesday, April 20, 1898.*]

HALL OF THE FRANKLIN INSTITUTE,  
PHILADELPHIA, April 20, 1898.

The President, MR. JOHN BIRKINBINE, in the chair.

Present, 198 members and visitors.

Additions to membership since last report, 29.

Prof. F. L. Garrison, chairman of the Committee on Library, gave an account of the present state of the work of re-arranging the library in the new fireproof stack-room, and congratulated the members on the circumstance that the work of transferring and re-arranging was now practically completed, and in a very satisfactory manner. He stated that a large amount of binding and repairing had been found necessary, and that the efforts made by the Committee to secure a fund of several thousand dollars, by subscription, for this purpose, had met with encouraging response.

Prof. L. F. Rondinella, chairman of the Committee on Science and the Arts, made a report of the present state of the work of that body. He renewed the request that the members of the Institute would aid the Committee by suggesting meritorious subjects for investigation.

Mr. Wm. F. Roberts gave a description of a novel form of motor actuated by carbon dioxide, the details of which are reserved for publication. The subject was illustrated by the exhibition and operation of several types of the motor, and evoked a very general discussion.

Mr. B. C. Batcheller, engineer of the Batcheller Pneumatic Tube Company, Philadelphia, read a communication on "Recent Progress in the Development of Pneumatic Despatch Tubes." The speaker gave a brief historical sketch of the subject, and described the special features of the pneumatic tube systems in the United States postal service, which embody the latest improvements. The subject was fully illustrated with the aid of lantern views.

The subjects above named were referred, for investigation and report, to the Committee on Science and the Arts.

Mr. H. Lyman Sayen described and illustrated the operation of certain improvements in X-ray tubes, which he had devised. These improvements consist, substantially, in a form of construction, whereby any desired and predetermined degree of vacuum may be attained by suitable adjustment, and, when once attained, is automatically maintained.

Adjourned.

WM. H. WAHL, *Secretary*.

## COMMITTEE ON SCIENCE AND THE ARTS.

[Abstract of proceedings of the stated meeting held Wednesday, April 6, 1898.]

PROF. L. F. RONDINELLA, in the chair.

Reports on the following subjects were considered :

*Franklin Institute Grand Medal.*—Discussed and referred to a special committee, to consider and report upon the scope of the medal.

*Trolley Car Fender.*—Henry Lotzgesell, Philadelphia. Discussed and referred back to the sub-committee to consider certain alleged anticipatory inventions.

*Improvements in Turnbuckles.*—E. W. Merrill, Brooklyn, N. Y. Passed first reading.

*Swivel Loom.*—Hermann Willmunder, Philadelphia. Passed first reading.

*The Abatement of the Smoke Nuisance.*—Referred by the Institute. Passed first reading.

*Disinfectant Ejector.*—Wm. B. Hollingshead, Bronxville, N. Y. Passed first reading.

*Tidal Motor.*—Ernest Markmann, Philadelphia. The Committee voted to reconsider its report on this case, and referred the subject to a new sub-committee.

The following reports were adopted :

*Wave Motor.*—Henry Lotzgesell, Philadelphia.

ABSTRACT.—This motor is fixed to a triangular float placed with its apex towards the approaching waves, and on each side of it are pivoted three vertical shafts having large vanes on their lower ends, which receive the impact of the waves and impart a partial rotation to the said shafts. The intermittent action of the waves is transformed into a continuous motion by well-known mechanical artifices, and the same may then be transmitted in any desired manner.

After having been moved back by the impact of a wave, the vanes are returned to their former position by weights appropriately applied to the vertical shafts, and other mechanical devices are employed when necessary to hold any or all the vanes out of action. [See U. S. Letters-Patent, No. 597,118, January 11, 1898.]

The report finds that the invention exhibits considerable ingenuity, but in the absence of practical tests no opinion is ventured as to its mechanical or commercial usefulness. [Sub-committee.—John Haug, chairman; G. Morgan Eldridge.]

*Automatic Water-Supply Cut-off.*—Samson Borgnis, Philadelphia.

ABSTRACT.—The object of this device is to effect, automatically, the stoppage of a flow of water after a certain predetermined interval of time. It consists of a valve which, when opened by hand, permits a flow from the source of supply. On the outlet side of the valve thus opened is a wheel with radial paddles, revolving in a tightly fitting case by the inflowing stream of water. The paddle-wheel, by means of connected gearing, is caused to release the valve previously opened by hand, effecting thereby a closure in the pipe

and the stopping of the flow of water. The interval of time elapsing between the opening of the valve by hand and its automatic closing is determined by the ratio of the gearing.

As shown in the model presented for the examination of the sub-committee, the device does not register a predetermined volume of water and then cut off the supply, as in the case of filling a tank, but is adapted rather for service as an attachment to a garden hose for watering lawns, in which the mechanism might be adjusted for a certain length of time for flow through a sprinkler.

The sub-committee investigating the device commends the applicant for the conception of the idea aimed at by his invention, and for the ingenuity displayed in his attempt to produce a mechanism for automatically controlling the flow of water and preventing waste. The report suggests in its conclusions certain modifications of the device which in the committee's opinion would render it more efficient and useful. The report was made advisory. [*Sub-Committee*.—Wm. M. Barr, chairman; Thos. P. Conard.]

*Pneumatic Bicycle*.—J. M. Baker, Lafayette Hill, Pa.

This inventor proposes to construct a bicycle frame so that both front and rear wheels are mounted to vibrate within the frame-bearings with a spring or cushioned support, and thus overcome the jolt and shock incident to riding.

Applicant submits to the committee certain sketches exhibiting the essential features of his plan of construction, and asks for advice as to its presumable utility. The report advises the inventor that his ideas are impractical. [*Sub-Committee*.—H. R. Heyl.]

#### FRANKLIN INSTITUTE AWARDS

which the Committee on Science and the Arts is authorized to grant or recommend, in the name of the Institute, in recognition of inventions and discoveries:

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The attention of investigators, inventors, authors and others, interested in the terms of the awards here described, is invited to the statement that the Committee on Science and the Arts of the Franklin Institute is organized for the purpose of undertaking the investigation of inventions and discoveries submitted to it, and that in cases deemed worthy of such recognition the grant of one or the other of the foregoing awards will be made or recommended.

The Secretary of the Institute will forward, on application, full information as to the manner of making application to the Committee for an examination and report upon an invention or discovery, or other contribution of value to the arts and sciences.

Members of the Institute are cordially requested to co-operate with the Committee, by bringing to its knowledge, or by recommending for investigation and report, subjects of a meritorious character. W.

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## SECTIONS.

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**MINING AND METALLURGICAL SECTION.**—*Stated Meeting* held Tuesday, April 12th, Mr. A. E. Outerbridge, Jr., President, in the chair.

Señor Raimundo Cabrera, of New York, presented a communication on "The Mineral Resources of Cuba" (read in the author's absence by Mr. Louis E. Levy). The author gave a comprehensive account of the notable occurrences of useful ores, minerals and building stones in the various provinces of the island, and a historical account of the attempts that have thus far been made to develop and commercially exploit them. The author dwelt strongly upon the past and present hindrances to the rapid development of the mineral industries in Cuba, arising from political conditions.

Mr. Multiades Th. Armus presented a paper on "The Reduction Works for Silver Ores at Arduana, Sonora, Mexico." The author gave a detailed account of the method successfully pursued, under his superintendence, in the metallurgical treatment of the very complex ores of this district. The above papers were referred for publication.

**CHEMICAL SECTION.**—*Stated Meeting* Tuesday, April 19th, Dr. W. J. Williams, Vice-President, in the chair.

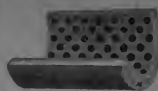
Dr. Wm. C. Day, Swarthmore, presented a communication on "A Method of Analyzing Commercial Phosphorus," in which he gave the comparative results obtained by the gravimetric and volumetric methods. The paper evoked a very general discussion.

Dr. Robert Bradbury presented a communication "On Chemical Equilibrium," giving a summary of the latest physico-chemical theories bearing on the subject. It was voted that the paper be made the subject of discussion at a future meeting.

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# THE JOURNAL OF THE

# FRANKLIN INSTITUTE

DEVOTED TO

\* Science and the Mechanic Arts. \*

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DR. WM. H. WAHL, Secretary of the Institute.

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OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

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VOL. CXLV, No. 6.

73<sup>D</sup> YEAR.

JUNE, 1898

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THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

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## Mining and Metallurgical Section.

*Stated Meeting, Wednesday, February 9, 1898.*

MR. A. E. OUTERBRIDGE, JR., President in the chair.

### THE PRACTICAL ASPECT OF PRESENT COMMERCIAL METHODS OF TESTING IRON AND STEEL.

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BY P. KREUZPOINTNER, Altoona, Pa.

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Before entering on the discussion of the subject of the paper I have the honor to read to you this evening, I beg permission to state the reasons why the subject of testing iron and steel deserves general attention. Just now we appear to be in a transitory state concerning not only our social and political but our commercial and industrial organization. Among other things, we are learning somewhat painfully that the popular cry of our inexhaustible resources, which for years has been dinned into our ears, has been leading us into habits of extravagances which, to unlearn, will take another generation.

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At the same time, it cannot be denied that the lavish use of our national resources has been instrumental in promoting our rapid development and in the attainment of our present commanding commercial and industrial position among the nations of the world.

The subject of small economies has become a favored study with engineers and managers of works at the present time, when financial success depends largely on the ingenuity displayed in the perfection of economic methods of production and management.

When it is found necessary for the manager of a furnace to expend \$40,000 for such improvements as will enable him to save 30 cents on the cost of producing a ton of pig iron; when the design of a heating furnace, promising the saving of 20 cents' worth of coal per ton of output, is anxiously studied by the manager; when the prices per pound of steel sold are calculated to the fourth decimal of a cent, and the saving of a hoop or two less on the barrels for shipping may represent all the profits on the investment in a year of depression, and when the increasing volume of available capital, with a consequent decrease of interest on the capital invested, compel the constructing engineer to provide for increased efficiency at a decreased cost, then we can readily perceive why the question of less quantity combined with better quality of the materials of construction has created a demand for means and methods to determine the most suitable qualities of these materials for a given purpose.

Thus the economic necessity of using the least permissible quantity of a material of approved quality has created an increasing demand for more or less elaborate systems of testing, inspecting and analyzing materials of construction. And since the results of the judicious application of the details of a system of testing involves questions of dollars and cents, success or failure, reputation or disgrace, of safety to life and limb, of freedom from anxiety and worry of various kinds, we may deem the consideration of the practical aspect of present methods of testing a question of economic value, a question of dollars and cents to the investor, to the director of a railroad, a

steamship line, or the stockholder of any concern, just as much as the profitable renting of a "skyscraper," of carrying passengers and freight, is a question of dollars and cents, the only difference being that the "skyscraper," the car or ship, carrying freight or passengers, is the end itself, while the testing of the materials used in building the "skyscraper," the car or ship, to make them useful as an interest-bearing investment, is a means to the end.

The measure of the value of a commodity is the proportional amount it takes to buy with it a given quantity of the necessities of life; or, conversely, how much we can buy of the necessities of life with a given amount of a commodity or its equivalent. If the commodity is worth much we get much, if it is worth little we get little. Similarly, the measure of the practical value of methods of testing iron and steel is the amount of knowledge we possess of the properties and qualities of these metals.

In other words, if we know much about the behavior of iron and steel under strain, our methods of testing will be the proper ones, and we will thereby obtain, or buy with that large amount of knowledge, if you please, a maximum of security, of safety, of reputation, of freedom from danger, anxiety and worry, of financial and social success for the investor and engineer. On the contrary, if our knowledge in this line of pursuit is inferior and defective, our methods of testing will be inferior and defective, and we can buy but a minimum of safety and success, with consequent loss through avoidable repairs, renewals, the use of more metal than is necessary, or inferior metal, and all this implies. Thus we perceive how proper methods of testing may become of high commercial value, a marketable commodity, as it were, of the knowledge we possess of the properties of iron and steel and the financially successful application of these properties.

Unfortunately, the effects of the work of proper or improper methods of testing are not so readily seen, demonstrable or calculable, as the correctness or usefulness of the structure can be measured, of which our work of testing is an essential part.

Let us examine for a moment what we are doing when we test a piece of iron or steel.

Testing will only then have a practical, that is, a commercially-economic value, if the method we use is in strict accord with the nature of the metal we test.

If the method is not in conformity with this essential requirement, which is the first principle in testing—that is to say, if by any method the metal which we test shows qualities different from those actually possessed by the metal we test—then our work of testing sinks to the level of an exhibition of the mechanical devices which we use for testing and of our skill in handling them.

All metals are viscous bodies, their viscosity being a matter of degree only and not of kind. Hence, the aim of testing must be to ascertain or measure the degree of viscosity possessed by the metal we test, and since it is the degree of viscosity which fits or unfits a metal to do a given work, it is obvious that methods of testing are of practical value in proportion to the degree of accuracy with which we ascertain the degree of viscosity of the metal we test and its natural behavior under strain.

Owing to the complexity of phenomena produced by the factors which tend to destroy a metallic structure, and to the inherent variableness of quality often found in the various members of a structure, or perchance in one of the members, and, owing to the want of opportunity by the engineer, which often prevents him, against his will, following up his observations to their sources by never-ending comparison with other similar metal, showing the same properties but varying qualities, there does at present not yet exist that uniformity of opinion concerning the properties and qualities of iron and steel, especially the latter, which is so desirable to produce the highest degree of economic value obtainable from a system of uniform methods of testing.

Of the various methods used at present to ascertain the physical qualities of iron and steel for structural purposes, the tensile test appears to be considered the most important and, therefore, the most widely used.

Although the value of the tensile test has been over-rated to a considerable extent, it is, nevertheless, an indispensable and most valuable guide in the realm of physical metallurgy. The engineer must have something tangible to base his calculations on, and this he can do only with the aid of the figures obtained in a tensile test.

Considering that a bending or nicking test of a whole bar shows its internal make-up as well and often better than the tensile test of a strip cut from that bar, it is within the limits of everyday experience to say that at present much time and money is spent for tensile testing of ordinary iron where a nicking test would answer the purpose and sometimes better.

The only advantage in such cases is that a tensile test is quite free from errors of judgment of the person making the test, while with a nicking test judgment and knowledge of methods of manufacture come into play if such a test is to be worth anything.

When making a tensile test, several different stages or phenomena attract our attention as the test proceeds.

In commercial testing these phenomena are defined as elastic limit, ultimate strength, per cent. of elongation, and per cent of contraction or reduction of area.

The elasticity of iron and steel is a complex function of the viscosity of the metal as a whole, the hardness of the individual crystal or fiber and the cohesive force by which these crystals or fibers are held together.

It is conceivable that the first strain applied brings the crystals or fibers into closer contact. If then the strain is released before sliding of the crystals and their deformation begins, they return or spring back to their original position, this action constituting the elasticity of the metals. If the strain is sufficient to produce sliding and deformation and the strain is released, the crystals will return or spring back only partly, while part of the deformation remains as permanent set. If now the strain continues without stopping, a point is reached where the viscosity of the metal comes into play.

At that point the metal begins to flow visibly, and flows so fast that, for a moment, it cannot hold up the weight or load

it had carried thus far. This point is indicated on the testing machine by the dropping of the scale-beam. If now the load is released there is a recoil as before, but it is very small, while the permanent set may be all the way from  $\frac{3}{100}$  to  $\frac{20}{100}$  of an inch.

After the drop of the beam the metal goes to destruction more or less rapidly.

Now it is this point when the beam drops which is called and assumed to be the elastic limit. Engineers and their inspectors use this drop of the beam in commercial testing almost exclusively, and of course the mills do not object as long as the consumer is satisfied.

In this illustration (*Fig. 1*) we can easily perceive the characteristic structural arrangement of a piece of steel.

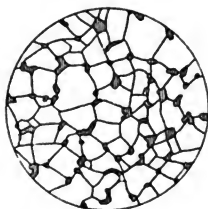


FIG. 1.

There are variations in size and form of structure, of course, according to per cent. of chemical elements and mechanical treatment, but since the effects of stresses are probably the same on all kinds of structures, the structure in this piece of steel will do as well for an illustration as any other.

Considering that the hard crystals of steel are imbedded in a softer matrix, and that, generally speaking, the proportion of this matrix is greater in the softer grades of steel, which brings the hard crystals farther apart in soft steel than in hard steel, it does not seem to require a great deal of imagination to perceive that the first stresses applied will tend to close up the spaces between the crystals by bringing them closer together and compressing somewhat the softer matrix in which the crystals are imbedded or surrounded. On release of the



stress the compression on the matrix is removed, and if the stress has been below the limit of compressibility of the matrix, the crystals will return to their original positions without themselves suffering distortion.

The hardness and size and shape of the individual crystals, the proportion and plasticity of the matrix, with all the complexities of variables produced by work and heat in the steel or iron, probably are the causes which, by their action and reaction, produce that apparent irregularity observed in taking the elastic limit and to avoid which a short cut is taken across lots, and the first interval of stretch without increase of load is taken as the elastic limit, which is the point when the beam drops temporarily.

Since limit of elasticity means that point where, on release of the load, the material strained assumes its original form and



FIG. 2.

dimensions, it is obvious that a point where the permanent set measures from  $\frac{3}{100}$  to  $\frac{20}{100}$  of an inch cannot be the limit of elasticity.

Viscosity is active to change the form of the crystals. The cohesive force has yielded to the extraneous force and permitted the crystals to leave their original position and slide upon each other. The structure of the metal being thus in a disturbed and permanently distorted condition, it is self-deception to accept the drop of the beam as the limit of elasticity and as a basis of the engineers' calculations.

In this sketch (*Fig. 2*) the top line is the elastic limit or limit of proportionality. Each of the following lines represents 1,000 pounds of load applied while the test piece was under stress in the testing machine. The fifth line was made when the beam dropped, which means that in this case the so-called elastic limit is 5,000 pounds higher than the limit found with

the dividers. The changes taking place in the metal at the various stages of load and stretch are approximately illustrated in the diagram, *Fig. 3*.

Along the base line from *O* to *A* the stretch of the steel tested for each 1,000 pounds load is given in hundredths of an inch.

The actual stretch from load to load is magnified in the diagram for better illustration. The distances on the diagram between each succeeding load or vertical lines denotes that peculiar stage in the life of iron and steel where, after the elastic limit is passed, the metal stretches without increase of load. On the piece tested, the stretches between the point of elastic limit at 38,000 pounds and the drop of the beam at 42,000 pounds

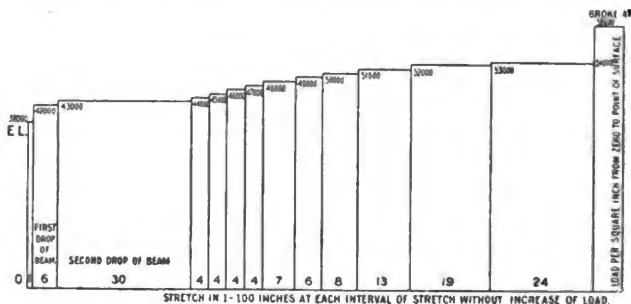


FIG. 3.

were so small, not quite  $\frac{1}{100}$  of an inch in 1,000 pounds, that they are not given singly on the diagram, but are included in the space between 38,000 and 42,000 pounds. If we now analyze the diagram, we find the elastic limit at 38,000 pounds. From there to 42,000 pounds is a total stretch, as already stated, of a hundredth of an inch. At 42,000 pounds the beam dropped and the test-piece stretched  $\frac{6}{100}$  of an inch until the beam rose again at 43,000 pounds; at that load it dropped again, and there was an interval of stretch without increase of load of fully  $\frac{3}{10}$  of an inch before the beam rose to mark a load of 44,000 pounds. For the next four intervals the stretch is uniformly  $\frac{4}{100}$  of an inch each, after which it increases rapidly for each 1,000

pounds load, until fracture took place at 58,600 pounds. One of the objections made against the present method of taking the elastic limit by the drop of the beam, or yield point, is that the drop is often not well defined, or that there are more than one drop, thus misleading the operator, who then, in order to make some showing on paper, gives whatever drop seems to him the most pronounced, or, worse still, what appears to him as a drop of the beam, producing results which are mere guess-work, a delusion and a snare. In the diagram, for instance, the first drop, being only one-fifth the duration of the second drop, is easily missed, and thus the engineer is persuaded to base his calculations on an elastic limit, at which the metal, if loaded to that point in actual service, would stretch and set permanently  $1 + 6 + 30 = 37\frac{37}{100}$  of an inch.

Another very striking example illustrating the foregoing is shown in the following results of tests of a bar of axle steel: The bar, after being forged to  $1\frac{1}{8}$  inches in diameter, was cut into three equal lengths of 18 inches each. Test No. 1 was left as coming from the hammer. Test No. 2 was heated to bright cherry and buried in charcoal dust to cool slowly. Test No. 3 was heated to bright cherry and left to cool down with the furnace.

The elastic limit was taken with the dividers by the author while the man, operating the machine, and who is quite expert in that manner of work, noted the yield point.

COMPARATIVE RESULTS OF ELASTIC LIMIT (LIMIT OF PROPORTIONALITY) AND THE YIELD POINT AS OBTAINED BY THE DROP OF THE SCALE-BEAM.

FIG. IV. No.	ELASTIC LIMIT.		YIELD POINT.		TENSILE STRENGTH.	ELONGA- TION.
	Pounds per Square Inch.	Per Cent.	Pounds per Square Inch.	Per Cent.	Pounds per Square Inch.	Per Cent. in 8 Inches.
1	46,000	48.3	57,800	60.7	95,200	19.5
2	42,000	48.1	46,400	53.2	87,200	19
3	38,000	46.2	50,600	61.4	82,300	22

Analyses of these results show the elastic limit of No. 1 to be 48.3 per cent., and of Nos. 2 and 3, 48.1 and 46.2 per cent., respectively.

The elastic limit, as obtained by the drop of the beam or yield point, is 60.7 per cent. in No. 1, 53.2 per cent. in No. 2 and 61.4 per cent. in No. 3.

These figures appear all the more significant when we consider the well-known fact, liable of proof by any one who desires to do so, that annealing above 900° F. lowers the tensile strength, elastic limit and the yield point in proportion to the degree of heat applied.

In Bauschinger's "Mittheilungen," Heft XIII, page 26, it is said on this point:

"The effects of heating above that temperature (450° C.) and the subsequent slow or quick cooling consists in lowering the elastic limit and the yield point, the more so the higher the temperature was. However, the effects are greater on the former than on the latter."

Accordingly, we find the elastic limit in the annealed pieces Nos. 2 and 3 lower than No. 1. But, while the yield point of No. 2 is lower than of No. 1, it is higher in No. 3, although No. 3 is lower in tensile strength than No. 2 by 4,900 pounds. Thus we see that the method of taking the elastic limit with dividers, crude as it is, is still more reliable for revealing the true condition of the metal under test than the drop of the beam, which not only gives too high a value, but also gives results contrary to the accepted theories and practical experience.

If the elastic limit is a complex function of molecular movement of the individual crystals and a sliding upon each other of these crystals, then the smallest permanent set means a distorted structure of the metal from what it was originally, and if we apply from 3,000 to 12,000 pounds more load beyond the point where this distortion begins or up to the yield point, which is that point in iron and steel under stress where stretch momentarily increases faster than the load applied, then we clearly reach a point where a breaking up of the structure is near, or at least an entire change of structure takes place, due to the visible stretching of the metal. Hence, since a release of the load at the point of elastic limit means a complete restoration to its original condition of whatever distortion the

metal may have suffered at that point, while a continuation of the loading or stress beyond that point means not only a permanent but an increasing distortion in proportion to increase of load, and since at the point in testing where the beam drops temporarily because the metal is weakened momentarily to such an extent that it cannot carry the load, which means, if it means anything, an entire and radical change of structure at the yield point, a change in quality different from the quality the engineer had based his calculations on, therefore, the present method of testing, where the drop of the scale beam or yield point is assumed to be the limit of elasticity of iron and steel, is unscientific and unpractical, and a mistake, because at that point the structure or part of a structure has taken a considerable and visible permanent set, while what is meant by the elastic limit is a return to the original length, breadth or thickness of the metal on the release of the load. Beyond this point the engineer deals with new and unknown qualities of the metal.

Rather than to be satisfied with mere guesswork and self-deception, it would be better not to take the elastic limit at all.

Methods of manufacture have reached such a point of perfection in well-managed works that it is unnecessary to take the elastic limit of every test-piece. To take it occasionally with care, patience and accuracy is more rational than to be satisfied with what in many instances amounts to a mere guess. If the author has laid particular stress on this subject, it is because the limit of elasticity in iron and steel is the turning point from the known condition of the metal on which the engineer bases his calculations to the unknown condition of a changed structure about which the engineer knows nothing, knows nothing of its future behavior, and which change of structure we have reason to believe marks the beginning of the fatigue of a metal.

There is all the less excuse to be satisfied with a mere guess and a self-deception, since there are instruments in the market for determining the elastic limit, which, while they may not be perfect, are a great improvement over the data obtained by the drop of the beam. The ultimate strength is a reliable

measure of the power of a metal to resist stress, although the engineer does not consider his structure ever to be strained to the point of destruction. It has been proposed by some to stop testing at the elastic limit, by others to take the breaking load instead of the ultimate strength as the measure of value.

However, there are practical difficulties connected with the attempt to determine the breaking load accurately, and the proposition has been abandoned.

To accept the percentage of elongation in a given test section is a practical and reliable measure of the ductility of iron and steel. The elongation is the measure of the degree of plasticity which gives to a metal the power to yield under shock, to cushion the blow, as it were. Hence, the more plastic a metal the more it will stretch, and, therefore, this stretch, expressed in per cent. of elongation in a given section, is the measure of the degree of plasticity of the metal we test.

However, the flow of iron and steel under stress, due to these metals having the property of being viscous, is easily retarded by improper shape of test section, and the elongation, as a measure of the flow or plasticity of metals, will be of practical value only then if the test section gives free play to the viscous action of the metal under test. The 8-inch section, now generally used, fulfills this requirement better than any other section used in commercial testing, and, therefore, the present method of measuring elongation may be considered of practical value.

The same cannot be said of contraction or reduction of area as a measure of the commercial value of iron and steel. While contraction of area is valuable to the expert in the testing laboratory, in everyday commercial testing there is no time to study the various phenomena producing certain effects, but must have a direct exposition of the factors which tend to destroy a metallic structure. This contraction of area does not do.

In theory, contraction of area is supposed to represent the degree of plasticity of a metal by assuming that every particle of the metal under test is in prime condition to stretch and flow to its maximum capacity, until the extraneous force, trying

to tear the metal apart, is able to overcome the cohesive force with which the particles are held together. Wöhler, who has done so much to advance our theoretical knowledge of iron and steel, and who was the father of contraction as a measure of quality, based his earlier specifications on the above assumption by making tensile strength, plus per cent. of contraction of area, equal 100, 100 being the standard for quality, with a minimum allowance of 95. This assumption, however, presupposed an ideal metal, which we seldom get with the everyday production of masses of metal for commercial purposes.

Even with the exercise of proper skill and care there is no puddle ball or steel ingot having all its constituent elements distributed so uniformly as to leave no more of them in one place than in another, thus causing a difference in structure with a consequent difference in density, which in turn leads to an inequality of flow and power of resistance to stress. Hence, the particles cannot flow uniformly and uninterruptedly, even if they were not hindered in doing so by laminations, and, since rupture takes place at the weakest point, so likewise is contraction determined by local conditions principally and not by the condition of the whole mass of metal except there be ideal uniformity.

Moreover, unlike stretch, which becomes a measurable quantity at an early stage of the testing, contraction takes place chiefly between the period when the ultimate strength is reached to the point of fracture. It is, therefore, the last gasp, as it were, in the life of the metal tested, and a careful engineer does not expect his structure to break down. The difficulty of measuring the per cent. of contraction with anything approaching accuracy also tends to make this method of testing an unsatisfactory and unreliable one from a practical standpoint.

The fact that contraction is not uniformly proportional to strength, but shows an irregular, varying percentage, while elongation is more or less proportional to strength, also shows that reduction of area is an exponent of local rather than general conditions.

With special high-grade steel, like gun forgings and short

test pieces, it may be that reduction of area has some practical value, but such exception cannot be applied to the enormous masses of structural material of all kinds produced and used under the stress of everyday competition and manifold applications.

While elongation is the resultant of the stretch of every cross section of the area stretched, hence gives an average of the total variations of the whole section, reduction of area gives only the ability to contract at that portion of the section where the test piece breaks, which point includes only a few of the many cross sections into which the section may be divided.

Therefore, the larger the test section, other things being equal, the less representative a quality-measure reduction of area is, leaving out now all other considerations. These few test pieces explain this very well.

The practical value of the drop test as a quality measure is more and more appreciated by the engineer.

Iron and steel, when repeatedly subjected to dynamic stresses, shocks, blows or vibrations, is affected differently than when only static stresses are active to destroy a structure or part of a structure.

During a tensile test there is ample time for the quick-flowing molecules of structural iron and steel to adjust themselves to new conditions, induced by the stress operating to destroy the metal. Under the sudden shock of a drop test every individual particle is put on its own merits.

If the cohesion with which the particles are held together is inferior, there will be separation under but a few blows. If there is irregularity of structure, microscopic nests or veins of impurities or flaws, then such defects will act like wedges driven between the structure, and fracture will be from inward out.

To resist sudden shock successfully, the metal must be able to transmit the vibrations caused by the blow on the particles directly struck from particle to particle in the shortest possible time. If the tremor caused at the point of impact is not conveyed or conducted away quickly and distributed uniformly throughout the mass of metal, if the tremor is arrested by flaws,



laminations, segregations, irregularity of structure, etc., or if the metal is too brittle, does not cushion enough, as it were, then the metal will soon separate along the cleavage lines of the crystals and break under a few blows.

Hence the drop test as a measure of shock-resisting power is a very practical method of testing, provided the blows are heavy enough. If they are not heavy enough to bring out the possible defects at the first two or three blows, every succeeding blow heats the metal, causing a change of structure, thus minimizing certain defects that may exist in the metal. The function then of the drop or impact test of any kind is, first, to determine the presence of such defects which mechanically separate the particles of the metal, or, in other words, impair their intimate contact and adhesion, and, second, to determine the ability of the metal, other things being equal, to absorb, as it were, to convey and distribute over every—even the smallest—cross section of the metal the vibrations produced on its surface by shocks, in order to prevent the overstraining, and hence fatiguing, of any cross section of the metal at the expense of its neighbors, thus producing early fracture.

The nicking and bending tests are extremely valuable, either for themselves or as auxiliaries to the tensile test.

Nicking a piece of steel or iron on one side and breaking it quickly will show several things. If iron, a nicking test will show whether it is clean or dirty, short fibered or long fibered, dry or juicy, coarse crystalline, due to cold shortness, or that fine, mushy, silvery granulation so characteristic of burnt iron. In steel the nicking will show laminations, shortness and, to a certain extent, want of uniformity of heating of the material in the mill, if there are many pieces of the same kind of metal to be tested..

The bending test is quite a reliable measure of ductility, more so for middling hard grades of steel, from boiler grade up, than for the softer kinds. Steel flows so easily under even moderate pressures that a dead-soft piece of steel must be very bad indeed if it will not stand bending double without signs of distress. What makes the bending test valuable with middling hard steel is the severe strain the bending imposes on the

cohesive power which holds the particles of the steel together.

Generally speaking, steel consists of two distinct bodies, a harder body, forming the crystalline portion, imbedded in a softer mass. We have reason to believe that the hard body predominates in the harder grades of steel, while it forms but a small percentage of the total mass in the soft grades. It is the soft body chiefly which imparts ductility to steel.

Now it is clear that, in order to produce maximum resistance to rupture, the union between these two bodies must be at its best in order to resist the severe strain on the convex surface of a bent piece of steel.

For this reason, if the convex surface has a velvety appearance without exhibiting the least skin cracks even, we have a right to conclude that a piece of steel thus tested is of very good quality, always provided that the bend is sufficiently large to strain the metal to its utmost. For these reasons also bending tests on square or cornered bars are more severe than on round ones. The above points are also applicable to iron with certain modifications.

Under certain conditions the nicking and bending test may become much more valuable and reliable as a quality measure than the tensile test.

The elongation, measured around the convex surface of a bent piece of steel, is often found to be equal, or a little more, to the elongation in a 2-inch section of a tensile test.

The nick-bending test is still more effective than the nicking test alone or the bending test alone. A piece of structural iron or steel must be very good indeed to suffer bending upon itself after having been nicked, which is meant by a nick-bending test.

Especially on steel is this a very severe test, because, if the crystals of steel are once separated anywhere in the mass, this separation is readily continued along the cleavage faces where the crystals adhere to each other by their sides. To be able, therefore, to bend a nicked piece of steel upon itself means superior cohesion of the particles, which, if the strength is sufficient, means an excellent material for constructive purposes.

The quenching test as a measure of quality and practical

utility may be considered of doubtful value. So many variables enter into the successful performance of this test that it is very easy to produce such conditions as will nullify the object we intend to accomplish.

A successful quenching test requires the uniformly carrying out of the details to be observed more accurately than any other test, because the heat employed will produce different effects from those we expect to get if that degree of heat is not in conformity with the point at which the chemical elements change in the steel.

The investigations of Osmond, Brinell, Charpy, Arnold, Hadfield, Saveur, Howe and others point to the conclusion that the changes in properties in steel due to heat treatment take final and definite shape within well-defined and somewhat-narrow limits. Below these limits complete change of elements does not take place.

In ordinary annealing, experienced judgment is a sufficiently close guide to produce the effects we desire. In the process of tempering tools we are guided by the variously-colored films of oxide forming on the steel.

In the specifications for quenching tests we usually find the empirical statement of "cherry heat," or the still-less intelligent expression "blood heat."

These terms are applied to all grades of structural steel, notwithstanding the fact that the effects we intend to produce by these degrees of heat are not alike on all grades of steel. In other words, since variation in the percentage of chemical elements in steel require varying degrees of heat to produce a desired change, the now uniformly applied so-called "cherry" or "blood heat" will produce varying effects on the piece quenched without our knowing what these effects really are.

Thus the operation of quenching as usually performed is a crude guesswork, a hit or miss performance, unjust to the manufacturer and misleading to the engineer.

To do justice with a quenching test to ourselves and others we ought to specify the chemical composition the material to be quenched ought to have, the degree of temperature at which that particular change of chemical elements takes place which

is to produce the effect we expect and desire, and the degree of temperature of the quenching fluid at which the change of elements in the steel becomes fixed.

Brief and incomplete as the foregoing explanation is, it will probably indicate that the performing of a proper and reliable quenching test requires knowledge of the carbon contents of the steel to begin with and the measuring, by means of a pyrometer, the degree of heat of the steel just as much as we measure the temperature of the quenching fluid. Only with the co-operation of these three factors can we claim practical usefulness for the quenching test.

Routine transverse tests are principally made on cast iron and other hard material.

On account of the absence of the restraining influence of grips or holders, every particle of the metal in a transverse test piece is free to act, and, therefore, such a test is a reliable measure of ductility and homogeneity.

Especially for cast iron this test is preferable to a tensile test of that metal. The ductility of cast iron is very small, and what little viscosity there is is overbalanced by the rigidity of the metal to such an extent that there is no measurable flow, and, therefore, fracture takes place with the beginning of flow, and no measurable elongation is obtained in a tensile test of cast iron. What little ductility there is is hindered from becoming manifest by the restraining influence of grips and the eccentricity of the pull of the testing machine.

Whatever eccentricity there is in a testing machine, however small, in the test of a cast-iron test piece it is sufficient to snap off the piece sideways before the small amount of ductility there is has time to assert itself. This is probably the reason that, while we get no elongation in a tensile test of cast iron, the same iron tested transversely will give from  $\frac{5}{100}$  to  $\frac{1}{10}$  of an inch deflection, showing that, while our method is in conformity with the nature of the metal under test, the other method is not.

Only when there is a long-continued series of cast-iron tensile tests made under the same conditions with the same mixture is a tensile test of cast iron of approximate value, because

then the error of eccentricity practically becomes inoperative as to result.

In the foregoing the author has not taken into consideration the possible influences of internal strains in cast iron, and of which Mr. A. E. Outerbridge has made so successful a study.

Crushing, shearing, punching and torsion tests are special tests, not used frequently as commercial tests, and, therefore, are not discussed at present.

Hammer tests are seldom made, although they are very valuable.

Drifting tests are used in bridge material, and are very effective tests for ascertaining ductility and homogeneity.

Fatigue tests will not come into general use as commercial tests because of the length of time necessary to make such tests.

At present we find specifications for fatigue test of stay-bolt iron in satisfactory operation. The underlying idea of this method of testing is to imitate the effects of the movements of a locomotive boiler, or rather its fire-box, caused by contraction and expansion on the stay-bolts of a boiler. While such imitation of natural causes can only be approximate, there is reason, nevertheless, to believe that such commercial-fatigue tests will prove of considerable practical value.

While the microscopic examination of iron and steel has not yet attained to the dignity of a commercial method of testing, yet the growing use of the microscope in mills and testing rooms gives promise that ere long this valuable auxiliary to the physical test and chemical analysis will be accorded its proper place as a standard method of testing, and thus justify the expectations of the pioneers of this valuable work, Sorby, in England; Martens, in Germany, and F. L. Garrison and C. Roepper, in this country.

The study of the microstructure of steel has not yet evolved fixed laws by which the practical value of a given structure of steel may be called standard.

But that much we know, that the microscope is to lead to a solution of some metallurgical problems, especially the effect of heat treatment, with all its apparent changes of structure and physical behavior.

From what little work the author has seen done with the microscope by others and has done himself, he cannot share the enthusiasm of those who claim that the microscope will supersede the chemical laboratory in its usefulness.

Summarizing our very brief inquiry into the practical aspect of present commercial methods of testing iron and steel, we find that in some of these methods we are following the laws of nature, while in others we are trying to squeeze the properties of these valuable metals into the straight jacket of conventional rules and methods with consequent unreliability of results.

Much as we know about the properties and qualities of iron and steel, there is still more to be learned.

However, there is a growing sentiment and desire in many quarters for information and thorough investigation, and the author sincerely hopes for the hearty co-operation of the Franklin Institute and the International Association for the Unification of Methods of Testing Materials of Construction, as well as the manufacturers and engineers of the country, to bring about that understanding of the properties and qualities of iron and steel and uniformity of methods of testing these metals for the mutual benefit of our commerce and our industries and the welfare and prosperity of our country and all countries, for science has no nationality.

#### DISCUSSION.

THE PRESIDENT OF THE SECTION:—I am sure that I express the unanimous sentiment of the members of the Mining and Metallurgical Section of the Franklin Institute when I say that we are much indebted to Mr. Kreuzpointner for his instructive and interesting contribution to our rapidly-growing literature upon the important subject of testing iron and steel.

The able addresses on this and cognate topics, which have followed each other month by month since the formation of this section a little more than a year ago, have proved that its creation was timely, and I am convinced that its future is bright with promise of still further expansion and usefulness.

Mr. Kreuzpointner has skilfully avoided falling into an error common to experts in discussing their specialties, of contracting their vision within the range of a very limited horizon; he has taken a broad view, and his introductory words recall to my mind some remarks of a French engineer, who visited this country about a year ago, and whose shrewd observations on the economics of American industries were extensively quoted in technical periodicals at home and abroad; he attributed the phenomenal advancement of this country in all mechanical industries mainly to the close attention given to technical details.

Mr. Kreuzpointner has unflinchingly pointed out facts in his discussion of the present methods of testing iron and steel, which may, perhaps, appear discouraging but knowledge of our shortcomings is really the first step towards advancement, and I think you will agree that there are a number of so-called "mysteries" waiting to be cleared up in connection with this subject. Sir Benjamin Baker marshalled before the engineering world many unexplained phenomena of metals in his presidential address at the "Institution of Civil Engineers," in 1895. If I correctly remember the substance of his remarks, he said something like this: "Who can tell what mysterious changes are occurring day by day, week by week, year by year, in metals, such, for instance, as hardened steel projectiles, leading sometimes to their violent disruption; who can explain that great mystery of the bridge links from the old Hammersmith Bridge made of the toughest iron, which, after successfully withstanding sixty years of hard usage, snapped in two by the score while being shipped to Edinburgh, although, when the halves of the broken links were subsequently thrown down from the top of the Forth Bridge on to the rocks 300 feet below, they bent like corkscrews, without fracture?"

Many years ago, Sir William Thomson (Lord Kelvin) showed that iron rods or wires, which were kept in torsional oscillation during the week, behaved very differently after a rest over Sunday, and these observations have been confirmed and elaborated by others. Sir Benjamin Baker stated that it has been recently shown that owing to the molecular settlement which occurs during rest in an overstrained bar,

the modulus of elasticity will rise 10 per cent. after three weeks' holiday.

The present methods of testing cast iron, and of determining therefrom the strength of castings made of this metal, are ludicrously or rather lamentably faulty, and they will, no doubt, so continue to be until engineers learn to appreciate more clearly the enormous influence that the rate of cooling exerts upon its physical properties. In this respect cast iron differs radically from cast steel or from other metals. The strength of cast iron test bars is not a safe guide upon which to predicate the strength of iron castings unless all of the relative conditions are known and taken into consideration. For instance, if you will cast from one ladle of iron two test bars, preferably in the same mold, one let us say, of 4 inch, the other of 1 inch section, turn them to the same dimensions and pull them upon a testing machine, you will probably find—I may say I am sure of it—that one of the test pieces will be *at least 50 per cent. stronger than the other!* I know that such a startling statement may seem incredible to any one not familiar with the facts, but I speak thus definitely and positively from experience.

The subject of Mr. Kreuzpointner's paper is open for discussion, and I am glad to recognize in the audience several gentlemen who are themselves experts in such work. I hope that they will express their views, and I will call upon Mr. Backstrom who, I know, has had years of experience in testing iron and steel, using the well-known "Emery" testing machine for that purpose, to say a few words upon the subject.

MR. G. L. BACKSTROM:—I do not agree with the author and his statement that cast iron has not perceptible elongation.

In numerous tests I have had occasion to make myself I have found elongations, ranging from '15 to '45 of 1 per cent., in cupola iron, and while specimen was under strain, and I think that the elongation of a cast-iron specimen will enable one to form a pretty good idea of the quality of the material being tested.

As to the difficulty of making reliable tests on cast iron, I lay that wholly to defective apparatus and carelessness of



operator. Proper preparation of specimen and a machine in perfect alignment will overcome these difficulties.

MR. JAMES S. WHITNEY:—Referring to tests of cast iron, I have in mind the "thermal test" now enforced by the Pennsylvania Railroad to try the quality of chilled iron car wheels. It may be remembered that this test consists in subjecting the cast wheel, when cold after annealing, to the sudden heat of a ring of molten metal poured around the chilled rim or "tread." This is done to roughly simulate the action of brakes, which on long down-grades is frequently sufficient to crack the gray iron plate of the wheel partially away from the tread by the expansion of the latter due to the heat generated.

The metal may be such as to stand the "drop test" and yet fail in the "thermal test." In view of the considerable differences in both the temperature and rate of cooling of molten cast iron of different chemical proportions, it would appear reasonable that some limits should be imposed as to the kind of molten iron to be used for this ring, and the pouring temperature. A close-grained metal used for brake shoes not only may come from cupola much hotter than wheeliron, but also loses its heat more rapidly at first, as our tests with an optical pyrometer have shown.

MR. KREUZPOINTNER made answer that the thermal test being a foundry test for wheels was not in his department, but that he believed it to be a good practical test, and that the requirement that the wheel should not break into two or more pieces within two minutes after pouring the ring, assured to the Pennsylvania Railroad a safer quality in the cast of wheels represented by the test wheel than if the drop test alone was relied upon.

At the wheel foundry of the Pennsylvania Railroad at Altoona molten wheel iron from the regular run for wheels is used for this test, and the moulders are quite expert in judging the temperature of the iron before pouring the wheels, being docked for loss of wheels poured too hot or too cold. Hence there is every probability that the iron used for making the thermal test is neither too hot nor too cold.

As to Mr. Backstrom's remark about there being some stretch in a tensile test of cast iron, I beg to say that I am

well aware of this fact. However, all my remarks made here to-night apply only to commercial methods of testing, and in the everyday practice of commercial testing it is simply out of question to use continually sufficient time and such scientific methods and elaborate instruments as are necessary to determine the elongation of a tensile test-piece of cast iron. Since the easily-measured deflection of a transverse test-piece of cast iron answers all the purposes of commercial testing, the latter method of testing cast iron appears to be more reliable, and therefore preferable whenever more or less rapid work becomes a necessity.

MR. ASA W. WHITNEY:—In the case of the drop test there appears to be a relation between the quality of resilience, as shown by the slow deflection of a transverse test bar, and the quality of metal which longest endures the shock of the drop test on a casting in form of a chilled wheel. Of course, this relation is complicated by the capacity of the metal for chill. But for same depth and quality of chill as shown in the wheel or chill test, the resilience  $\left( = \frac{\text{stress} \times \text{deflection}}{2 \times \text{weight of bar}} \right)$  of 4" area hexagon bar indicates quite fairly the quality or relative number of blows under the drop test when in form of a chilled wheel. Only by very close regulation of cupola charges for many years on a strictly chemical basis has it been possible to observe the relations of this kind in the narrow ranges of figures indicating practically equivalent chemical compositions. Further study may indicate a similar physical relation to the thermal test besides limiting chemical composition in certain directions, though thorough annealing is a very important point.

## THE RIGHT TO PROPERTY IN AN IDEA.\*

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## DEFINITIONS.

Webster defines the term "property" in part as follows:

"*Property*.—(3) The exclusive right of possessing, enjoying, and disposing of a thing; ownership; title. (4) That to which a person has a legal title, whether in his possession or not; thing owned; an estate, whether in lands, goods, or money.

"*Literary Property*.—Property which consists in written or printed compositions. The exclusive right of publication as recognized and limited by law."

## INTRODUCTORY.

The avowed object of all honest anarchists, socialists, reformers of every class of opinion and degree of intelligence; the dreams of all philosophers, poets, and prophets; the teachings of every professor of ethics, morals and economics; the mission of all governments and of all religion is to cause men everywhere to understand the principles of justice, to incarnate them in their lives as a controlling motive power and force, inspiring and guiding their thoughts and actions. All efforts of the past; all agitations of to-day, all hopes for the future having as an objective point the betterment of the whole of humanity, morally, socially, and economically, may be rightly interpreted as a demand for justice. Every cause for discontent; every political issue will be permanently and satisfactorily removed or settled when all men recognize that so far as human agencies in the affairs of men are operative, justice is done. A review of the past, a careful summary of the present aspect of all public questions teaches and emphasizes one fact: *The people want justice, but they do not know how to obtain it.*

\* A lecture delivered before the Franklin Institute, November 26, 1897.

*Justice* is born of honesty and intelligence. *Honesty* is the image of God in the hearts of men. *Intelligence* is a condition of mind. Granting the presence of honesty in the hearts of the people, their lack of knowledge as to how to obtain justice and their failure to secure justice must be ascribed to defective intelligence. Honesty will cause all men to wish to do justice, but the degree of justice which they do will be measured by their own standard, by their conception or understanding of the principles of justice. If the action of any man is unjust, the cause of the injustice must issue either from a deficiency in honesty or a defective intelligence. As all whose opinions are worthy of consideration claim a full measure of honesty, attention need be directed only to their mental development.

Close observation will disclose the fact that in their attempts to obtain justice those who have directed the thought and energies of the people have centered attention upon efforts to formulate and enforce demands for justice, rather than upon efforts to so educate men as to cause each one to do justice, under any and all conditions, whether his action is directed towards a fellow-man, a family, a municipality, State or nation, or the universal society of humanity. The universal demand for justice can be satisfied by each man doing justice, and in no other way. The problem of how to obtain justice for all men, individually and collectively, will be completely and correctly solved by causing the actions of all men, individually and collectively, to be just. When individual action is just, collective action will be just also. Just collective action is impossible so long as collective society, large or small, is composed of men whose conception of the principles of justice is defective. It is the duty of all who study the welfare of humanity from the view point of the rights and duties of the individual or from the rights and duties of collective society, any grouping of individuals, large or small, to give the problem of how to cause every individual action to be just their most serious attention. This question once solved, all other problems for the moral and economic betterment of the people will become simple and easy of solution or cease to exist.

## THE RIGHT TO PROPERTY IN AN IDEA.

The best test for the correctness of a person's conception of the principles of justice, or of his honesty, is his willingness to recognize, and, recognizing, to give compensation for the right to property in an idea. This is true, because ideas, being the most intangible of all products of labor, are the most difficult to protect by the requirements and punishments possible to enacted law. Many persons whose moral sense of right and wrong is sufficiently clear to protect them from any desire to steal anything protected by enacted law feel no restraining influence from their conscience to retard them from taking anything not so protected and appropriating it to their own benefit without tendering compensation to its author, even when they know the author, and know he has need of a just compensation for his labor. The necessity for plainly-stated enacted laws, defining what may and what may not be freely taken for the exclusive use or enjoyment of individuals, singly or collectively, is created by the inability of many persons clearly to perceive the principles of justice, to understand their requirements, and to govern their actions in accordance therewith. Compensation is due from each individual for every intellectual benefit received, to some person or group of persons working collectively for educational, charitable, religious, or industrial economic purposes; or for the proper government of a municipality, State, or nation, or for all of humanity.

Defective moral vision causes those who are benefited by society and government to feel no rebuke of conscience when they neglect their civic duties. The most important function of society or government is the protection of individuals in their just right to life and property. The necessity for such protection is the basis of the right of governments to exact the payment of taxes for their support. This necessity, and the taxation caused by it, will become less and less arduous as enacted laws become more just and are honestly and intelligently obeyed or executed.

An idea unexpressed is in the undisputed possession of him who conceives it, but it has no tangible existence. It cannot be communicated to others without being given a form, more

or less tangible, in words or signs voiced or written. When given a tangible existence, by what rule of justice can it become, without compensation, the property of another not its author. In so far as society fails to give to an author the protection necessary to enable him to enforce his right to property in his own ideas, society permits every one to take and use them freely, without rendering compensation for them. It permits those who will to be legally unjust. In this way the interests of authors are sacrificed for the common good. A law clearly securing to every author the right to property in his ideas will not prevent any author from becoming a public benefactor. He can voluntarily relinquish his right, by deed to the government, and thus enrich all to whom his ideas are of value, and by the same act prevent others from claiming a property right in them.

#### THE RIGHT TO PROPERTY IN DISCOVERIES AND INVENTIONS.

The right to property justly adheres to the acquisitions of close observations resulting in the discovery of gems, precious metals, useful natural materials and mechanical principles; and in the invention of devices for controlling and utilizing the resources and forces of nature. In every department of thought a mind may project itself beyond the boundary of the discovered and broaden the sphere of knowledge by making clear that which had not previously been understood, or bringing to view the hitherto unknown. The right to property in ideas that lead to such results, and to the results obtained by them, is as just as the right to property in the things produced by manual labor employed to mould the idea into a concrete form that can be offered for sale as a new creation. It is the duty of society to do justice by protecting every author, discoverer, and inventor in his right to property in his ideas as well as in the products of his physical labor.

#### AUTHORS MUST PAY THEIR DEBTS.

While every person should be protected in the ownership of all that is justly his own, no person should be protected in the ownership of more than his own. Every useful idea, dis-

covery or invention is based upon the work of those who lived before. Every person who now makes a tool or writes a philosophical statement is assisted by the work of those who have passed to a sphere where rights to property are unknown, and also by the labor of his contemporaries. By that order of nature which sets a limit to the life of the body, the results of the work done by those who once lived, and which they once rightfully owned as their property, become the common heritage of all the living. The dead cannot own property.

Improvements, additional adaptations, new ideas and inventions, are suggested to the minds of careful observers. In this manner are induced all improvements in industry; facilities of every kind; comforts of every description; entertainments of every class, and the power more perfectly to utilize the resources and forces of nature. Out of the stock of common knowledge ideas spring. The known suggests that which may be known.

If ideas, discoveries and inventions are suggested by observation of what others have done, what is due to society from authors, discoverers, inventors, in fact, from all owners of property? If society had failed to protect the laborer in his right to own the results of his labor; if the author, discoverer or inventor had been denied an opportunity to observe existing things, to draw upon the resources and forces of nature which are the property of no one, but are a part of the common inheritance; or, if they had been debarred from all access to the stock of common knowledge, is it conceivable that the product of labor would have been saved, or that the idea, discovery, or invention would have been his?

The principles of justice operate with impartial force upon the conduct of individuals towards society, as upon the conduct of society toward individuals. The requirements of justice which confirm to each person all that is rightfully his own, require that he shall have no more than his own. More than is rightfully his own no one can have without doing an injustice to another. To do justice every person must give to society full compensation for the benefits he receives from society, not only for its protection of his right to property, but

for the assistance he obtains from existing things, from natural resources and forces, and from the stock of common knowledge. The man who causes two blades of grass to grow where but one grew before, and keeps both blades for himself, together with all knowledge of how he accomplished such a result, is not a benefactor of his race. His benefaction, if any, is in proportion to the division he makes with others of his extraordinary increase, and the extent to which he permits his valuable knowledge to be diffused, without compensation, through the stock of common knowledge, thus making it a free heritage of all.

The reimbursement to society, voluntarily or exacted, for benefits received, intangible or tangible, is a requirement that cannot be determined with exact justice. The human mind is not yet sufficiently endowed with the power of intelligent judgment and honest action to enable it to do complete justice under all conditions. It must be content with doing substantial justice, being guided thereto by the demands of equity.

#### COPYRIGHT AND PATENT LAWS.

Copyright and patent laws are framed on the principles of equity. They should give equal recognition to the rights of individuals and of society. They should divide an accruing benefit for a brief period between an author and society, and beyond that transfer the entire increment of information to the stock of common knowledge from which all may take freely. The life of an individual is brief. The life of society is continuous. It is good policy to offer a proper inducement for the desired achievement. The highest good of society, of any collective group, as of individuals, requires that it shall develop itself to the best of which it is capable. This is its right and its duty. If, by securing to an author, discoverer, or inventor of a useful idea or thing an opportunity to realize for his own a profit, during a part of his life, no matter how large, profit cannot be out of proportion to usefulness, society can stimulate all minds to do their best, it will not only enrich itself by the activity of the living, it will inherit rich endowments from those who pass beyond the jurisdiction of its enactments.



If there were, however, never a question as to the right to property in an idea, discovery or invention, there would be a necessity for copyright and patent laws, and for the system of administration founded upon them. On account of the fact that all ideas, discoveries and inventions are outgrowths of suggestions from the known, it is a common occurrence to have several persons, almost simultaneously, honestly claim to be the original and only pioneer to lead and advance in literature, science, art or industry. To make and keep correct records whereby conflicting claims so arising may be justly settled, is as important, and, if the judgment of all men were perfect, would be the only function of government in such cases. Founded and administered to do justice, society can better afford to broaden than to restrict the application and scope of its copyright and patent laws.

#### WHAT IS PROPERTY?

The inquiry may now be made in its broadest sense, what is property?

Property consists of all things of value which may be owned by the consent of society, given in recognition of its conception of the principles of justice, by an individual, or by any collective group. The *property quality* of things of value is created by the consent of society practically expressed through the means it employs to protect owners in their right to possess, enjoy, and dispose of that which they may legally own. I say *consent of society*, because there can be no property where there is no social consent or contract to protect anyone's right to possession.

If no one recognizes a thing as having value, no one wants to own it, therefore, no protection is required to make possession of it sure. It is not property. A thing recognized as having value, ownership of which is not confirmed by the consent of society, cannot be exchanged for other things having value, because all are permitted freely to take it, therefore no protection is granted to make possession of it sure. It is not property. Things of value, the ownership of which is not confirmed by the consent of society, are those things upon which

no labor has been expended. Justice requires that every laborer shall be unmolested in the possession and enjoyment of the products of his toil. In recognition of this demand, society grants protection for the right to own all things created by labor. This protection constitutes such things property.

#### THE BASIS OF THE RIGHT TO OWN PROPERTY.

It is now necessary to examine the basis upon which the right to own property rests.

The consent of society to the ownership of things of value is based upon its conception of the principles of justice. This conception of justice is expressed by enacted law. The divine law is the moral and the enacted law is the legal basis to all right to own property. This right is founded on the natural right of a creator to possess the products of his creation, his labor. This is the demand of justice. This right is conceded by all who honestly and intelligently demand or seek to do justice. This is the basis of the title to all property whether owned individually or collectively by two or more persons for their private use and benefit, or by associations, municipalities, States, or nations for the common use and benefit of all members, citizens or subjects.

Protection is assured by the operation of moral and physical forces. The most effective protection is given by a correct understanding of, and a desire to obey moral law. Moral law teaches honesty as a principle. Economic law enforces honesty as a practice. Man must understand and willingly obey the principles of moral law before he can understand and correctly apply the principles of economic law. When no person will permit himself to be unjust there will be no injustice. Barring the factor of knowledge, the absence of which may render one unable to determine to whom a thing of value rightly belongs, the right to property will be completely protected without the presence or the use of enacted law, or of its representative physical forces, when the moral law is correctly understood and universally obeyed.

Once, when walking in Central Park, New York, I chanced to hear a few words exchanged between two young girls who were walking near me:

"Let's pick some flowers," said one.

"Oh! I daren't," answered the other.

"Come on, the policeman won't catch us, he is around the turn in the walk behind the bushes," persisted the first.

"I daren't catch myself stealing," replied the second, as she passed on, admiring but not touching the flowers.

If the high sense of honor, the clear-sighted self-respect of that little girl controlled the actions of every person, stealing would be an unknown vice, the protection of property by physical force would be an unknown burden upon the industrious.

In proportion as self-respect is strong or weak, asserting and maintaining a high standard of honor in individuals and in society, is the right to property respected or disregarded. Regard of the right to property determines the position of an individual in the scale of moral development, from vicious brute to conscientious man. In proportion as regard of the right to property is strong or weak in individuals and in society are men civilized or brutal, and in proportion as men are civilized or brutal, do they recognize and respect the sacredness of life and property.

A clear recognition of the right to property is necessary to the protection of life. This is illustrated daily by the acts of men engaged in robbery or the wanton destruction of property. When so engaged they do not hesitate to take life to save themselves from capture. It is conceded that the right to life is valued above all other rights. It is clear that protection of the right to life and property is based on justice, and is made most effectual by a correct understanding of and disposition to apply the principles of justice. The intelligence to recognize these principles, the power to incarnate them and to make them a governing force guiding his every action, raises man above the brute and constitutes him another and a higher order of being. There can be no moral or economic government among brutes.

Whenever a change occurs in the popular conception of the principles of justice, either through a clearer understanding or a misinterpretation of moral law, and by reason of such change society withdraws its consent to the ownership of any

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class of property, all things so affected cease to be property. Against the destruction of property by such a cause property owners have no defense. When a popular verdict has once declared that the right to own a certain thing or class of things shall cease, owners of such property are powerless to maintain the right to ownership even though they defend it with their lives. This fact has an epoch-making illustration in the destruction of property in slaves caused by the withdrawal of the consent of society to such ownership, voiced by the emancipation proclamation issued by Abraham Lincoln, President of the United States.

#### LIMITATIONS ON THE RIGHT TO OWN AND USE PROPERTY.

The natural right of every person to own and use as he pleases the products of his labor, his ideas, discoveries and inventions can be fully exercised only when he is isolated. In a state of isolation there is no property. As soon as a man associates with another his natural right to do as he pleases with his own is modified by a due regard for the similar rights of others. By association society is formed. The welfare of society requires that protection to the right to property it grants for individual good shall not be used to the injury of anyone, or of society. Should it be, it is the duty of society, in defense of its welfare, to withdraw consent and thus destroy the property. The fundamental principles of justice require that all property shall be owned and used with a due regard for the similar rights of others. Rights to the ownership and use of property are not vested rights. They are not absolute. They are qualified by the principles and conditions that give them existence.

The expenses of government incurred in behalf of the protection it affords to the ownership of property must be collected from the property it protects. Government frequently exercises its sovereign power and dispossesses the owner of property, by public sale, to satisfy its claims for taxes, giving title to the buyer. Rights to property that can be thus annulled are not vested rights. They are not absolute. They are created, and may be destroyed by the consent of society.

In a final analysis it is clear that the ownership of all property is protected, not by constitutions, enacted laws or decisions of courts, but by the consent of society based on its conception of the principles of justice. Changes in the popular conception of these principles or of their proper application may cause existing constitutions, enacted laws and court decisions to be out of harmony with the popular belief as to what is just and right. Such a change will cause existing conditions to appear unjust. A people stung to the quick by a sense of injustice, believing themselves to be the victims of unjust laws, an unjust administration of laws, or of an unjust industrial, commercial or financial system, will not cease to agitate, nor ought they to cease to agitate, until every change is made that is necessary to bring the constitutions and enacted laws upon which court decisions are based into strict accord with their conceptions of the principles of justice.

Such changes are steps of progress in civilization when in the right direction. They are steps of retrogression when in the wrong direction. When they come by the peaceful processes of evolution, the new absorbs and utilizes all of good that can be found in the old with injury to none. When they come by the destructive processes of revolution the suspicions, prejudices and discontent of the people, having brewed an anger that cannot be controlled, it bursts forth in a wild fury and destroys the old in order to secure an opportunity to create a new government or an industrial system that will accord with their conceptions of justice. It is not in the power of any man or class of men permanently to prevent the oncoming of these changes. Delayed they may be. Directed they can be. No power can stop them absolutely. The life of nature finds expression in change. When changes cease, humanity and all nature will be dead. It is idle to resist a tendency to change. It is the highest wisdom to guide it in a right direction.

These truths should cause everyone to realize that all rights to property, of whatever kind, depend upon the correct moral and economic education of the people. Every property owner should realize that the protection of his right to ownership depends primarily upon a correct conception of the principles of justice by the people, not upon the use of force. When

an appeal to force is made sufficiently drastic to arouse all of the people, it will be found that millions who toil wield the balance of power, and that they cannot wield it justly when they are not guided by a correct conception of the principles of justice. A state of inaction cannot be maintained. History is repeating itself. Conditions are rapidly developing, such as lead to revolution. Men can remain free only by recognizing the correct principles of justice and properly applying them in every detail of their affairs. Happiness cannot exist without freedom. Freedom cannot live when justice is not done. The time has come when the American people must make progress by means of correct moral and economic education or by revolution.

#### THE ECONOMIC LAW OF LABOR AND PROPERTY.

The natural law of labor and property is founded on the principles of moral and economic law. Being a natural law it is universal in its application and binding upon all men. In discussing this subject elsewhere I have said:

"In isolation a man has undisputed possession of the surplus products of his labor. \* \* \* The natural right of the isolated to the undisputed possession of the product of his labor and to be unrestricted in the use or disposition he may make of it cannot be enjoyed by associated men except as it is qualified by a due regard for the similar right of others. This is the foundation of the natural law of labor and property.

\* \* \* \* \*

"If, prompted by an ignorant self-interest, one man decides to take more than his just share of the joint product of himself and others, because he is stronger and has the brute power to do so, such a violation of natural moral law removes the transaction from the domain of economic science and carries it back to the domain of moral science. The brute must be taught the moral law, and have intelligence enough to understand it and honor enough to obey it before he can be dealt with as an economic factor."\*

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\* "The Law of Incorporated Companies, Operating Under Municipal Franchises." See chapter under the title of "The Economic Law of Labor and Property." Robert Clark Company, Cincinnati, O.

The laborer and the capitalist must yield obedience to the requirements of justice if justice is to be established. Neither can secure a permanent gain by violating the economic law and taking an unjust share of their joint products. Justice cannot permit any person to be a permanent gainer by his own acts of injustice.

#### THE NATURAL LAW OF JUSTICE.

The natural law of justice is superior to all constitutions, all enacted laws, all court decisions. It is uninfluenced by the opinions or actions of men. It is the only correct ideal. It is the only changeless standard. Rightly understood and obeyed it will enable all men to realize the highest attainable good. Disregarded, whether through ignorance or through vicious selfishness, it punishes with imperious and merciless exactness every step of divergence from a true course. In no age have the ablest men comprehended all there is of wisdom. In every age the toiling masses have failed to understand and to utilize all the wisdom formulated for their guidance and the betterment of their condition. Slowly and painfully they have been working their way towards the realization of higher and still higher ideals, sometimes helped and many times hindered by their trusted leaders. The entire experience of mankind confirms the correctness of the theory that man is ennobled or degraded by the truth or error contained in his beliefs. Whenever a clearer understanding of the natural law detects an error in a conception of the principles of justice, and the affairs of men are re-aligned in accordance with the requirements of the new light, civilization and human happiness make a distinct gain. Whenever a conception of the principles of justice is clouded by suspicion, prejudice or vicious selfishness, and the affairs of men are blindly aligned by false standards, civilization receives a disastrous blow. Happiness is stabbed in its heart.

In this aspect of the subject it is a solemn duty to direct attention to the fact that thousands of advocates are ceaselessly working to miseducate the people. They are poisoning the minds of the people with sinister suggestions and prejudices founded on falsehoods, to which they give currency in the

guise of facts. They are creating a sense of injustice by magnifying imaginary wrongs. They are preparing the way for a widespread destruction of property through the dissemination of false conceptions of the principles of justice. If their work is not promptly and thoroughly counteracted by correct moral and economic education, a disaster, such as the cause of civilization has not suffered since the dark ages, will come. Political development has reached a point at which choice must be made between doing the work of correctly educating the people or suffering the disaster of a revolution.

This is neither the time nor place to amplify this note of warning. But I beg to assure everyone to whom these words may come that they are written with a full knowledge of their serious import based on facts that admit of no doubting. These facts have been made possible by the activity of the dishonest and of the misinformed; and also by the apathy of those who rely upon enacted law and the use of force to protect them in the possession of that which they call their property. Unless property owners perform their civic duties far more perfectly than they have done in the past, the day will come when this reliance will fail them. Millions of workmen are being taught that the property of the wealthy has been acquired by robbery, and that, "*When a man is robbed, the way for him to get money is not to work for it but to fight for it.*" When that idea has taken possession of a sufficient number, the power of existing enacted laws to protect the right to such property will fail. The destruction of one class of property to satisfy demands not correctly based on the natural law of justice will not satisfy, it will only stimulate the anger of the misguided. A well-defined movement in a wrong direction cannot be stopped until it has gone far beyond the limits originally assigned for it by those through whose ill-judged work its inception and momentum are due. On the day when those having false conceptions of the principles of justice gain control of the government, municipal, State or national, calamity will come. The falsity or correctness of any person's conceptions may be shown by his ability or disposition to recognize the right to property in an idea. This is the kind of property most difficult to protect by law,



therefore it is the most easily stolen. A man who will steal because he safely can is honest or just only when he must be. A man who is honest or just only by compulsion has not the spirit of honesty or justice in him.

#### AN ECONOMIC DELUSION.

All men are endowed with equal natural rights but not with equal natural conditions or capabilities. The teaching that "All men who do their best do the same"\* is an economic delusion. No one more readily recognizes differences in capabilities than honest-hearted, clear-headed men who work under the direction of others.

Whatever a person may justly claim is his by right, not by favor. Less than this no man should be permitted to demand or receive. What one cannot give in justice to himself another cannot justly take from him. Justice to self is a true measure of justice to others. The Divine command is, "*Do unto others as you would have others do unto you.*" This command requires every man to be sure that his own acts are just, rather than to be the judge of the actions of others by demanding justice for himself. No man can comply with this command without doing justice. No man can obey this command who fails to recognize the differences in natural or acquired capabilities existing between himself and others.

The history of mankind presents a panorama of the rise and fall of civilizations. Men have ever been reaching after but have never fully grasped and comprehended the great truth which teaches the two-fold character of the products of life—character and property. The greater always includes the lesser interest, yet men for ages have blindly sacrificed character for the sake of property. Every feature of the economic law of labor and property must be correctly understood and rightly obeyed before a person can develop the best possible character. Moral law is the foundation of economic law. Economic law completes moral law. One cannot be rightly observed while the other is being violated.

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\* "Equality." Edward Bellamy.

## THE TREASURES OF WISDOM.

All that has been said pertains to ideas that may be made tangible, imprisoned in concrete forms and offered for sale in the market place. They are of the earth. Beyond them, enveloping them, as the earth is enveloped by its atmosphere, is the realm of thought. There the society of mind exists; a society in which property is unknown. There the wise of all ages hold communion. There consent is given not to own but to freely take all that any one is capable of receiving. None can hear the conversation of the wise who cannot understand them. In that society the property values for which men so earnestly contend have no meaning. The treasures of wisdom need no guarding. They elude destruction. They increase by being shared. In the realm of the society of mind it is clearly understood that the things of greatest value are priceless. There no one will sacrifice character for property. There one would be known as a loser who should give his character, his soul, in exchange for the whole world. What infinite folly is it then for practical business men to risk an impairment of character to gain even the largest wealth anyone has ever been able to grasp. No man can be unjust to a fellow-man and wrong him out of the enjoyment of anything that is justly his without blindly sacrificing the greater for the lesser good. All so inclined should know that it is impossible for the justice of God, which overrules the affairs of men, to permit anyone to be a permanent gainer by acts of his own injustice. In the name of all who labor, justice is demanded by all who wisely, or unwisely, work for social reforms. For the welfare of all who toil with hands or brain let everyone be taught to be just. When all are just, the right to property in ideas, or in any other form, will need no guarding, no affirmation.

## THE FRANKLIN INSTITUTE.

*Stated Meeting, Wednesday, April 20, 1898.*

### RECENT IMPROVEMENT IN X-RAY TUBES.

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BY H. LYMAN SAYEN.

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The most important considerations in the manufacture of Roentgen-ray apparatus are those influenced by the value of the apparatus to physicians and hospitals. Now that the scientific world has recovered from the suddenness of this discovery of æther-energy, which is so closely allied with light and electricity and yet without experimental proof of the nature of its energy, investigation goes on with surer and even more-rapid strides than it did immediately after Professor Roentgen's announcement.

Investigators, both physical and medical, have become specific in their lines of research, and the large demand for apparatus has caused such competition among manufacturers that many useful improvements are the result. The manufacturers themselves, perhaps, do as much practical work in this direction as any one else. They know the faults of their own apparatus, and these deficiencies are ever before them in complaints from operators, so that it is quite a problem to furnish a good outfit capable of being easily managed by a physician or layman with satisfactory results for any length of time.

An induction coil or static machine will, with any reasonable care, last indefinitely. The manipulation of the dry plate is the same as in ordinary photography, requiring only a knowledge of developing, fixing, etc. The difficulties are chiefly met with, however, in the operation of the high-vacuum tube, in which so many factors are to be considered in achieving satisfactory work. Up to the present time I do not believe that there has been discovered a more-efficient generator of X-rays than a piece of platinum bombarded by so-called "radiant matter."

Here it may perhaps be interesting to indulge in a little speculation on "radiant matter." Faraday, who first used the

expression, defines it thus, "If we can conceive a change as far beyond vaporization as that is above fluidity, and then take into account also the proportional increased extent of alteration as the changes rise, we shall, perhaps, if we can form any conception at all, not fall far short of 'radiant matter,' and as in the last conversion many qualities were lost, so here many more would disappear." Dr. William Crookes, in 1876, made public his highly-interesting experiments with tubes carried to such a degree of exhaustion that the gases therein were in the so-called "radiant" state. In his papers he calls attention to the fact that gases are composed of an almost infinite number of small particles or molecules, which are constantly moving in every direction with velocities of all conceivable magnitudes. Owing to the great number of these molecules it is impossible for them to move an appreciable distance before they collide with one of their fellows. If the pressure of the gas be diminished, the distance which the molecule can move is proportionately increased. This average distance he calls the mean free path of the molecule. If the pressure be so decreased that the mean free path is comparable with the dimensions of the containing vessel, the matter is then in the so-called "radiant state," and the molecules are free to bound forwards and backwards across the tube. These molecules radiate from a negatively-excited pole with enormous velocity, producing many phenomena wherever they strike. Crookes constructed a number of very ingenious tubes to show the novel and characteristic properties of radiant matter, and he assigned the following properties to it: Radiant matter exerts a powerful phosphorogenic action where it strikes. It proceeds in straight lines. When intercepted by solid matter it casts a shadow. It exerts strong mechanical action where it strikes. Radiant matter produces heat when its motion is arrested.

To show this last property, he made a small tube containing a thin platinum plate placed in the focus of a converging stream of radiant matter. A weak current from the secondary of an induction coil is sufficient to heat the platinum red hot. Had Crookes gone a little further in his experiment he would have found that not only heat and phosphorescence manifest them-

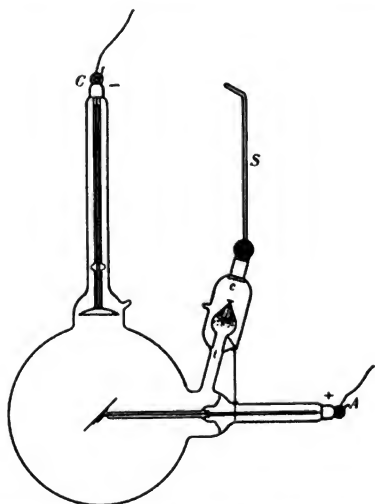
selves, but also that these molecular collisions give rise to an æther disturbance of such a character as to excite phosphorescence not only inside the tube but also outside of it. It would also have been demonstrated that this disturbance radiates in straight lines, suffering no refraction, reflection, or any other of the phenomena incident to ordinary light, and that all substances are more or less transparent to it. In this way he would have antedated Professor Roentgen by more than thirty years.

Whether the X-rays are simply the result of the enormously high temperature produced by the impact of the molecules, whether they are due to oscillations set up in the charges on the discharging atoms, or whether they arise from an entirely different cause, is yet to be determined.

The original tube used by Roentgen was similar in construction to one I now show you. In this, the bombardment is on the glass at the spherical end of the tube. The efficient X-rays resulting are few, because it is impossible to bombard the glass very hard without cracking or melting it; a considerable portion of the rays are absorbed in traveling through the thick glass at the end of the tube, and, to get a sharp picture, the light must be considerably cut off by a diaphragm. Practically all forms of tubes were tried by the early investigators, the one finally found most efficient was discovered at King's College, London, in 1892. It was the Crookes hot-platinum tube. This is the fundamental form of tube used by various makers throughout the world to-day, though with considerable modifications as to detail arrangement. It was not long, however, before a great difficulty manifested itself in the use of high-vacuum tubes for X-ray work, and that was the rise in vacuum subsequent to their constant use. Many attempts were made to remedy this defect, but they all lacked success from the very fact that the vacuum was in too a fickle a state for the human hand to manage. The vacuum in a Roentgen-ray tube can vary only over very small limits, and, being also dependent on the temperature of the tube, it is in a very unstable position. Thus, if a tube starts to heat when running, the vacuum lowers and the tube takes more current, due to the

increased conductivity of the gas therein, lowering the vacuum still more; a reversed condition of affairs takes place if the tube starts to cool. It will, therefore, be seen that it is very difficult and often impossible to keep the temperature of a tube constant, and to manage a non-automatic regulating device. The ideal regulating device should possess the following qualities:

- (1) It should act immediately.
- (2) It should be independent of the temperature of the tube.



*C*, cathode terminal ; *A*, anode terminal ; *S*, adjustable spark point ;  
*c*, cathode auxiliary tube ; *l*, communicating tube ;  
*B*, potash bulb.

- (3) It should maintain the desired vacuum unvaryingly.

Having these difficulties in mind and the qualities desired, I designed for Queen & Co. a tube, which I fully described before the Electrical Section of the Institute about a year ago. It is unnecessary in this connection to do more than refer to the principles involved in its construction. Its operation depends upon two phenomena, viz., the variation of the electrical re-

sistance of the gas in the tube due to different degrees of vacuum, and to the fact that certain salts will give off vapor on being warmed, re-absorbing it on cooling.

A reference to the figure will make the operation of the tube clear. A small bulb containing a substance which gives off vapor on being heated and re-absorbs it as it cools is directly connected to the main tube and surrounded by an auxiliary tube, which is exhausted to a low Crookes vacuum. In the auxiliary tube the cathode is opposite the above-mentioned bulb, so that any discharge through it will heat this bulb. This cathode is connected in an adjustable spark point, which can be set at any desired distance from the cathode terminal of the main tube. In operation, the induction coil is connected as usual to the main bulb. On starting the coil, the vacuum of the main tube being high, its resistance is also high, and the current takes the path of least resistance through the auxiliary tube, thereby heating the substance in the small bulb. This will continue for a few seconds, until a sufficient amount of gas has been evolved to bring down the resistance of the main tube. After this only an occasional spark will jump across the gap sufficient to maintain the tube at the same vacuum. As the spark point is adjustable, the vacuum may be set high or low by varying the distances between it and the main tube.

Practical work has demonstrated that a tube must possess the following characteristics in order to secure efficient results:

(1) The vacuum should be adjustable to permit the ready employment of the tube in various kinds of work.

In a radiograph of the hand, it is desirable to use a low vacuum in order to secure good contrast between the bones and the flesh, while a high vacuum is necessary to locate foreign metallic bodies in the denser muscular or bony tissues.

(2) It should require a minimum amount of attention from the operator during the operation.

(3) It must be able to hold its vacuum continuously for an indefinite period.

(4) It must be able to carry a large current in order to generate powerful X-rays, thereby consuming as little time as possible in making the exposure.

(5) It should have sharp definition, *i. e.*, the source of X-rays should be as small as possible without interfering with the efficiency of the tube.

In designing the tube shown in the figure, and which I shall now put in operation, all the foregoing points received careful consideration. The principle of self-regulation is identical with that first employed in the original design. This tube is made in two sizes, one with a larger bulb and heavier platinum suitable for powerful currents. In the larger tube the platinum is reinforced by welding an extra thickness underneath, the platinum being very thick immediately under the focal point of the cathode stream. The cathode is made of aluminum, hand-hammered to prevent rapid deterioration. It is ground and polished to a curve of a radius of one inch. It may seem curious, but it is a fact, that the rays focus at a point, the distance of which from the cathode is dependent on the height of vacuum. After once having come to a focus, they seem to continue in the form of a pencil until they strike the platinum. The cathode rays do not cross each other at all. This is not true, however, for very low vacua in which they do cross.

The small bulb containing the gas-producing substance is made with a conical side towards the bombarding cathode, in order that the heat shall be well and evenly distributed over its surface. This allows the substance to get the full benefit of the heat generated without the liability of the bulb cracking, due to an excessive current. The conical point of the bulb is protected by sealing in it a little piece of platinum wire welded to a piece of foil of the same material.



## THE ZEUNER DIAGRAM.

BY WILLIAM FOX,

Assistant Professor of Applied Mathematics.

(Concluded from vol. cxlv, p. 393.)

*Problem 10.*—Given (Fig. 1) points  $C$ ,  $P$ ,  $A$ , and  $L$ . A line through  $L$  perpendicular to  $AL$  will cut the line  $CP$  (produced) in point  $E$ .

*Problem 11.*—Similar to Problem 9. Given points  $L$  and  $D$ . The perpendiculars drawn to  $LC$  and  $DC$ , through the points  $L$  and  $D$  respectively, will intersect at the point  $E$ .

*Problem 12.*—The lines through  $EB$  and  $ED$  are respectively perpendicular to the lines  $CB$  and  $CD$ .

*Problem 13.*—(Fig. 2)  $ST$  is perpendicular  $CN$  at  $C$ . Any two of the indefinite lines  $CM$ ,  $CE$  and  $CK$  (Fig. 1) being given, the third one is found by making the angles  $MCE$  and  $ECK$  equal. Lay off distance  $CI = i$  on  $CT$ . Through point  $I$  draw a line parallel to the line  $CR$  bisecting the angle  $\alpha = KCN$ . This line intersects  $CE$  in point  $F$ . Make  $CO = CF$  and draw  $OK$  perpendicular to  $OC$  and cutting  $CK$  in point  $K$ . Then will  $CK = r$ .

$$\text{For} \quad \frac{i}{CO} = \frac{\sin. \frac{\eta}{2}}{\cos. \frac{\alpha}{2}} \text{ (as in Probl. 6.)}$$

$$\text{Hence} \quad CO = r \sin. \alpha = CK \sin. \alpha$$

Another solution may be obtained by assuming any value for  $r$  say  $r_1$ .

$$\begin{aligned} \text{Then} \quad & r_1 (\cos. \beta - \cos. \overline{\alpha - \beta}) = i_1 \\ \text{and} \quad & r (\cos. \beta - \cos. \overline{\alpha - \beta}) = i \end{aligned} \quad \left. \vphantom{\begin{aligned} \text{Then} \\ \text{and} \end{aligned}} \right\} \text{(Eq. 5.)}$$

$$\text{Hence} \quad \frac{r}{r_1} = \frac{i}{i_1}$$

where  $r$ ,  $i$  and  $\beta$  are known, and which can be solved graphically in the usual way.

*Problem 14.*—From equations (1) and (2) we get

$$p = r - r \cos. \beta + i$$

$$(p - i) = r (1 - \cos. \beta) = 2 r \sin^2. \frac{\beta}{2}$$

$$\frac{(p - i) \cos. \frac{\beta}{2}}{\sin. \frac{\beta}{2}} = 2 r \sin. \frac{\beta}{2} \cos. \frac{\beta}{2} = r \sin. \beta$$

or

$$(p - i) \tan. \left(90^\circ - \frac{\beta}{2}\right) = r \sin. \beta \quad (8)$$

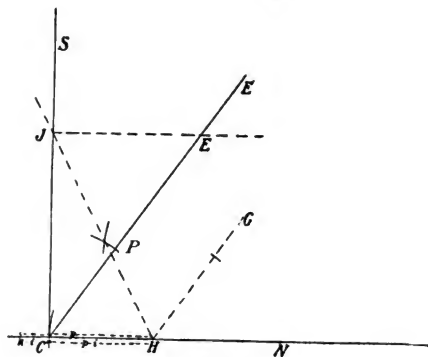


FIG. 4.

Given the point  $C$  and the perpendiculars  $CS$  and  $CN$  (Fig. 4). On  $CN$  lay off  $CH = p - i$ , and draw through  $H$  a line  $HG$  parallel to the  $\beta$  line  $CE$ ; bisect the angle  $GHC$  by the line  $HJ$ , cutting  $CS$  in point  $J$ . The line  $JE$  drawn perpendicular to  $CS$  will cut the  $\beta$  line in point  $E$ , giving  $CE = r$ . The lap is found by laying off the distance  $EP = p$  on  $CE$ .

From the figure we see

$$JC = HC \tan. JHC = CE \cos. ECJ$$

$$\text{or} \quad (p - i) \tan. \frac{180^\circ - \beta}{2} = CE \sin. \beta$$

Comparing this with equation (8) above, it is evident that  $CE = r$ .

*Problem 15.*—This is the *bête noir* corresponding to Spangler's Problem IV.

I suggest the following solution as being somewhat simpler than Professor Spangler's:

Draw the lines  $CN$  and  $ST$  (Fig. 5) as before.

On  $ST$  lay off  $CI = i$  and  $IY = p$ , then  $YC = p - i$ .

Draw the line  $CK$  making the angle  $KCN = \alpha$ , and on  $CK$  lay off  $CY' = CY$ . Project the point  $Y'$  on  $SC$  to point  $Q$  and draw the arc, laying off  $CQ'$  on  $CN$  equal to  $CQ$ . At

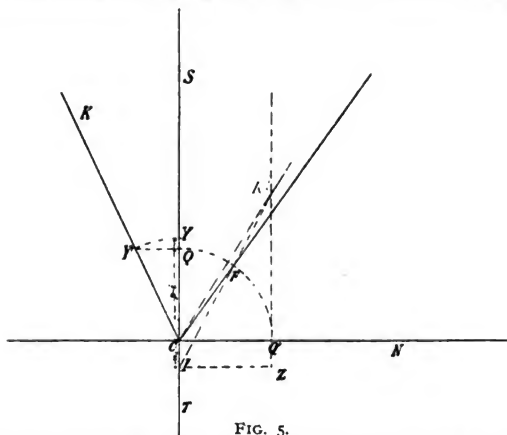


FIG. 5.

$Q'$  erect a perpendicular and find the point  $R$  where a line bisecting the angle  $\alpha$  intersects the perpendicular.

Join  $R$  and  $I$  by a line, cutting the circle  $QQ'$  at the point  $F$ . Then will the line  $FC$  make the angle  $\beta$  with  $CN$ .

*Proof:* Prolong the line  $RQ'$  to the point  $Z$  making  $Q'Z = i$ .

$$RQ' = Q'C \tan. RCQ'$$

$$= Y'C \sin. \alpha \tan. \frac{\alpha}{2}$$

$$= Y'C \cdot 2 \sin.^2 \frac{\alpha}{2}$$





Fig. 6, similar to Fig. 5, shows the work, the scale being twice the scale of Fig. 1.

It is evident that  $\angle CFI = \angle FCA + \angle ZIF$

$$\text{Hence } \frac{i}{(p-i) \sin. \eta} = \frac{\sin. (FCA + ZIF)}{\sin. (90^\circ - ZIF)} = \frac{\tan. ZIF \cos. FCA + \sin. FCA}{1}$$

$$\text{where } \tan. ZIF = \frac{(p-i)(1-\cos. \eta) + i}{(p-i) \sin. \eta} \text{ like eq. (A)}$$

Comparing this with Equation (11), we find  $\angle FCA = \beta$

Problem 17.—Equation (9) gives

$$r = \frac{p}{1 - \cos. (a - \beta)} = \frac{p}{2 \sin.^2 \frac{a - \beta}{2}}$$

$$\text{or } r \sin. \frac{a - \beta}{2} = \frac{p}{2 \sin. \frac{a - \beta}{2}}$$

Draw circle with radius =  $p$ , center  $C$  (Fig. 7).

Lay off the given angles  $BCA = \beta$ , and  $DCA = a$ .

Bisect the angle  $DCB (= a - \beta)$  by line  $EC$ .

Make  $FC = \frac{1}{2} p$  on a line  $CM$  perpendicular to  $BC$ .

Draw the line  $FE$  parallel to  $BC$  and cutting  $EC$  in point  $E$ .

Make  $E'C = EC$ , and draw  $E'R$  parallel to  $BC$  and cutting  $EC$  (prolonged) in point  $R$ . Then will  $CR = r$ .

COLLEGE OF THE CITY OF NEW YORK,

NEW YORK, March, 1896.

## CHEMICAL SECTION.

*Stated Meeting, Tuesday, March 15, 1898.*

### SOME RECENT DEVELOPMENTS IN TEXTILE PROCESSES.

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BY ARON HAMBURGER.

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The cry of the civilized world is, and has always been, for novelty. In the multitude of mechanical and industrial pursuits which engross the attention of the busy worker in laboratory and shop, wonder succeeds wonder; the world, astonished perhaps for a moment, looks on with languid interest, and then demands further proofs of the fact that we are but on the threshold of industrial development.

The fickleness of fashion, the demands of an ever-active competition, and the various problems presented by the inexorable laws of supply and demand, have ever been a powerful stimulus to the textile worker, as well as to his co-laborers in other fields of industry.

A few developments of comparatively recent origin seem to promise new avenues for the skill of the textile worker, and it is my purpose to present to you in a few brief, practical notes, a number of new applications of chemistry to textile processes which are engrossing the attention of American and European mills and dyehouses.

On account of its high luster, great strength and elasticity, and its affinity for nearly all artificial and natural coloring matters, the fiber excreted by the many species of silk worm has always held the highest place in the estimation of textile-manufacturing nations.

The great demand for silk for ornamental and useful purposes, and its high intrinsic value, have been the incentives for many efforts towards its artificial production.

While nothing has yet been brought forward which has been capable of displacing silk in the textile industry, interest-

ing progress has been made in the art of imparting a silk luster and appearance to other and cheaper fibers.

As early as 1844 John Mercer, a cotton printer, of Lancashire, England, discovered that, when subjected to a strong solution of caustic soda or caustic potash, cotton fibers became greatly contracted in length, as well as more dense, and to a high degree capable of being directly dyed with basis dye-stuffs.

He made this discovery the basis of broad patents, which were issued to him in England and in continental countries in 1850, and, to quote the original patent application, his claims were as follows:

"The invention consists in subjecting vegetable fabrics and fibrous materials, cotton, flax, etc., either in the raw or manufactured state, to the action of caustic soda or caustic potash, dilute sulphuric acid, or chloride of zinc, of a strength and temperature sufficient to produce the new effects, and to give the new properties to them which I have hereafter described.

#### MERCER'S INVENTION DESCRIBED.

"The mode I adopt of carrying into operation my invention to cloth, made wholly or partially from any vegetable fibers, bleached, is as follows: I pass the cloth through a padding machine charged with caustic soda, or caustic potash, at 60° or 70° Twaddell's hydrometer, at the common temperature, at say 60° F. or under, and, without drying the cloth, wash it in water, then pass through dilute sulphuric acid and wash again, or I run the cloth over and under a series of rollers in a cistern with caustic soda or caustic potash at from 40° to 50° of Twaddell's hydrometer, at the common temperature of the atmosphere, the last two rollers being set so as to squeeze the excess of potash back into the cistern; the cloth then passes over and under rollers, placed in a series of cisterns charged at the commencement of the operation with water only, so that, at the last cistern, the alkali has been nearly all washed out of the cloth; when the cloth has either gone through the padding machine or through the cisterns above described, I wash the cloth in water, pass it through dilute sulphuric acid, and wash it again in water.



"When I adapt the invention to gray or unbleached cloth, made from the fibrous material before mentioned, I first boil or steep the cloth in water, so as to have it thoroughly wet, and remove most of the water by the squeezers or hydro-extractor, and then pass the cloth through the soda or potash solution, etc., and proceed as before described.

#### MERCER'S INVENTION APPLIED TO WARPS.

"I apply my invention in the same way to warps, either bleached or unbleached. By this process I produce on cotton and other vegetable fabrics and fibers effects somewhat analogous to that which is produced on woolen by the process of fulling or milling. It will have acquired greater strength and firmness, each fiber requiring greater force to break it. It will also have become heavier than it was before it was acted on by the alkali, if in both cases it be weighed at the temperature of 60° F. or under. It will have acquired greatly augmented and improved powers of receiving colors in printing and dyeing.

#### EFFECTS OF THE APPLICATION.

"The effects of the application of my invention to the vegetable fiber in any of its various stages before it is manufactured into cloth will be readily understood by reference to its effects upon cloth composed of such fibers.

"Secondly, I employ sulphuric acid diluted to 105° Twaddell's hydrometer, and at 60° F. or under. I use this acid mixture instead of caustic potash or soda, and operate in all respects the same as when I use soda or potash, except the last souring, which is here unnecessary.

"Thirdly, when I employ solution of chloride of zinc, instead of soda or potash, I use the solution at 145° F., and operate in all respects the same as when I use soda or potash.

"When I operate on mixed fabrics, partly of vegetable and partly of silk, woolen, or other animal fibers, such as delaines or leans, etc., I prefer the strength of the alkali not to be above 40° Twaddell's hydrometer and the heat not above 50° F., lest the animal fibers should be injured.

## CONCLUDING REMARKS.

"I may, in conclusion, remark that the description of the apparatus or machinery and the strength and temperature of the soda or potash, sulphuric acid or chloride of zinc solution, may be varied to a considerable extent, and will produce proportionate effects without at all deviating from my invention. For instance, caustic potash or soda may be used even as low as 20° Twaddell's hydrometer, and still give improved properties to cotton, etc., in receiving colors in printing and dyeing, particularly if the heat be low, for the lower the temperature the more effectively the soda or potash acts on the fibrous material above described. I, therefore, do not confine myself to any particular strength or temperature of the substances I employ, but the particular strength, heat, and processes here described are what I have found the best, and what I prefer.

"And I claim as of my invention the subjection of cotton, linen and other vegetable fibrous material, either in the fiber or any stage of its manufacture, either alone or mixed with silk, woolen or other animal fibrous material to the action of caustic soda or caustic potash, dilute sulphuric acid, or solution of chloride of zinc of a temperature and strength sufficient to produce the new effects, and to give to them the new properties above described, either by padding, printing or steeping, immersion or any other mode of handling."

Notwithstanding the great expectations aroused among cotton manufacturers by Mercer's patents, so-called mercerized cotton has, until recently, assumed little importance because the contraction of the fiber in all directions made cotton cloth so treated much more expensive, and the advantage gained never appealed to the handler as being sufficiently strong to compensate for the increased cost of production.

Within the last two years, however, an accidental discovery in connection with mercerizing cotton has opened a new field of usefulness for this process, and the silk-lustering of cotton yarns or cloth by means of solutions of caustic alkalies or similar reagents, presents many possibilities.

A textile chemist in Germany, whose name at this writing escapes my memory, was experimenting with a fabric com-

posed of equal parts of silk and cotton with a view to the acquisition of some means by which piece goods of this description might be colored evenly in one bath.

In one experiment he treated his cotton yarns with a strong solution of caustic soda while holding same in a stretched condition, and, to his great surprise and delight, noted the fact that the cotton fiber had assumed a silky luster and appearance, and could be dyed in very fast and bright shades without losing its fine silk-like appearance.

As a result of this happy accident, manufacturers in all parts of the world have been experimenting on similar lines, and, through the courtesy of the J. R. Montgomery Company, of Windsor Locks, Conn., which is very successfully manufacturing these silk-lustered cotton yarns on a large scale, I am enabled to present for your examination some very handsome samples of this yarn, which is easily dyed and may readily be woven into durable and handsome fabrics.

To obtain this silk luster and finish, the best method to be pursued is as follows: Yarns, warps or piece goods in a stretched condition are immersed in a solution of sodium hydrate (caustic soda) for about fifteen minutes, strength of bath to be about 52° Twaddell.

The cotton goods thus treated are then passed through squeeze rolls, or are hydro-extracted, to remove excess of alkali, and are then thoroughly rinsed with clear water.

A second bath of dilute sulphuric acid suffices to neutralize all remaining alkali, when a thorough final rinsing leaves the yarn in condition for either dyeing or bleaching.

The character of yarns employed for this purpose has a marked influence on the luster and finish obtained, as soft-twisted and double yarns made from long staple Egyptian or Sea Island cotton give decidedly the best results. Hard-twisted yarns and single yarns of ordinary cotton acquire luster and a greater affinity for dyestuffs, but they are inferior in appearance to those made of soft-twisted double yarns from Egyptian or Sea Island cotton.

As a result of the uniform contraction of the fiber, due to this process, these yarns have a tensile strength of from 25 to

40 per cent. greater than before treatment, and this property adds greatly to the advantage to be derived from the use of such material in the manufacture of articles for ordinary wear.

The silk touch and feel or "scroop," as it is called, may be obtained on mercerized yarns by treating them after dyeing or bleaching with alternate baths of olive-oil soap and calcium chloride, as follows:

The dyed or bleached yarns (or cloth) are first passed through a bath made up of one pound neutral olive-oil soap dissolved in twenty-five gallons of water. The yarns are then hydro-extracted and passed through a 1 per-cent. solution of calcium chloride, and afterwards washed and steamed lightly.

This precipitation of a lime soap (principally calcium oleate) on the fiber imparts the peculiar silky feeling so much desired in the manufacture of dress goods, hosiery, underwear, etc.

Where this scroop is not of particular benefit, it is always well to soap the dyed or bleached yarns or goods with a good neutral olive-oil soap, which adds softness and improves the luster.

To insure even lustering I have always found that it is better to use a weaker solution of alkali and longer immersion therein, rather than a stronger caustic bath and a shorter treatment.

A 52° Twaddell solution of caustic soda is as strong as necessary, and the average time of immersion should not be over fifteen minutes.

Stretching and twisting on suitable machines after the mercerizing, also tend to heighten luster, and are recommended to all handlers of this material.

Since the first notes on this method of silk-lustering appeared, many other reagents have been recommended in the place of the caustic alkalies, but few if any of them appear to present any practical advantage.

One method, patented in Germany, calls for the use of a mercerizing bath made up of 30 per cent. of sodium or potassium sulphide, to which is added 10 per cent. of any of the following fat solvents (which float on top of the alkaline sulphide solution, so that the yarns or cloth pass first through the sol-

vent and then through the sulphide), methyl or ethyl alcohol, benzol, aniline oil, paraffine oil, petroleum or turpentine.

As the yarns or goods treated with caustic soda or potash are, as a rule, boiled out and freed from impurity before entering the bath, this method, which I have carefully tried, costs more than the other, and does not seem to give any better results.

Another application of this mercerizing process to textile fabrics is mentioned in a late number of the *Textile Manufacturer*, of Manchester, England, from which I quote:

#### GLOSS ON COTTON AND LINEN GOODS.

"Among the very recent processes for obtaining a silk-like gloss effect on fibers and fabrics is one devised by the *Farbwerke*, of Hoechst-am-Main, and described in the *Textile Manufacturer*, of Manchester, England.

"The object of this is to produce durable effects on both cotton and linen stuffs. To do this they employ the modified mercerizing system of Thomas & Prevost, by applying appropriate resisting styles capable of neutralizing the mercerizing effects of soda lye upon the fabric in the state of tension. By these means they claim to obtain a new, valuable and technical effect." It is known that it has been impossible hitherto to produce damask-like gloss effects of perfect durability by means of the dyeing or printing processes. The methods employed until now were, as a rule, limited to printing with oxide of zinc, barium sulphate, etc., combined with a fixing agent (albumen, caseine, etc.), on tissues of sateen-like weaving and gloss dressing in order to thus neutralize the sateen gloss, and of the tissue by means of this locally-fixed white color. While the gloss produced by this sateen weaving cannot be compared with real silk gloss and with that obtained on cotton by Thomas & Prevost's system, and must be regarded merely as an effect of weaving and a particular method of dressing, it is to be observed that the silk gloss of mercerized cotton in a state of tension is obtained by a chemical and physical change of the cotton fiber.

"It is a fact that the mercerizing of the cotton in a state of

tension causes the lumen of the fiber to shrink, to become transparent, and to undergo great changes on its surface which produce this lasting silk-like gloss. Also, from a chemical point of view, the fiber undergoes an advantageous change, and it is generally known that, since Mercer's experiments, the affinity of cotton fiber towards mordants and dyestuffs is considerably increased by the influence of strong soda lyes and agents acting in a similar manner (concentrated sulphuric acid, solution of chloride of zinc). It is, therefore, possible to produce this mercerizing effect on fabrics locally, under conditions as specified by Thomas & Prevost (tension), either by means of printing with concentrated soda lye or by protection of the fiber against the mercerizing effect of the soda lye, a durable and damask-like effect being thus obtained. The substances suitable for the resisting style are easily coagulable organic bodies, such as albumen, caseine, etc., as well as salts, acids or oxides, which partly have a neutralizing effect, or provide the fiber with a protecting film of an oxide.

"The resisting action of these bodies against soda lye is not new. With the help of these bodies the most varied white and colored gimping effects were obtained, while the object of the present process is to avoid the shrinking of the tissue and the silk gloss thus caused.

"In the description of a German patent particular stress is laid upon the circumstance that the printed resisting style—albumen, caseine, etc., or mixtures of gum with acetates of aluminium or chromium—becomes insoluble by previously steaming, and thus forms an inseparable compound with the fiber. In order to obtain the intended effect, the applied resisting styles need not be steamed, and the possibility thus created of effecting a subsequent removal of the albumen, or the encrusting protecting substances, is in many cases a great advantage. As the silk-like gloss produced on the tissues in form of patterns, according to this method, is very durable, such cloths may be afterwards dyed, printed, steamed and washed without danger to the gloss. It is likewise possible to produce the most varied printing effects with durable silk gloss by the addition of mordants or dyestuffs to the resisting styles or to the mer-

cerizing soda lye. The printing of the resisting styles and the mercerizing may be done separately or in succession on the printing machine; in the latter case the printed cloth, on leaving the roller, is stretched by means of an appropriate stretching apparatus. The washing in a stretched condition is continued until the tension of the inner fiber has ceased.

"The following is an example of an appropriate printing color:

"Mercerizing color for direct printing, 70 grams British gum and 930 grams soda lye (40° B.), or 100 grams wheat starch, 200 grams water, and 2,000 grams soda lye (40° B.).

"*Resisting Color.*—Albumen solution, 10°, 700 grams, and dilute solution of gum tragacanth 300 grams.

"We might add further that the microscopical appearance of cotton mercerized by the process of Thomas & Prevost differs from that of ordinary cotton in a striking and typical manner. The mercerized fibers mounted in water generally appear stretched and smooth, only showing the twisted appearance in places, or not at all. Those fibers which possess the well-known twisted appearance have a large lumen and are little changed. The fibers from the outside portion of the yarn show, in consequence of the greater tension, longitudinal folds, while those from the inside frequently show transverse crushed folds.

"The surface of the fibers often shows an intermittent double stripe. The cuticular layer is generally completely demolished. The lumen of the fibers in places is greatly enlarged; in others it appears as a dark line, while in others it has entirely vanished. The enlarged portions of the lumen are frequently filled with a granular mass. In polarized light the fibers behave just like ordinary cotton."

The extensive use of mohair and lustrous wools in the manufacture of braid yarns and dress goods, etc., has led to many experiments with ordinary wools to secure silky appearance and luster, and while a perfectly satisfactory process has not yet been obtained, some very interesting results of a more or less practical value have been arrived at through the use of various oxidizing agents, most prominent of which are chlorine and bromine in dilute solutions.

The combination of fatty-acid precipitation with energetic oxidation by means of sodium or calcium hypochlorite is the basis of the following formulæ, which have given me good silky luster, but which have a more or less tendering action on the fiber.

For light shades on 20 pounds of knitting yarn, take the soluble part of 3 pounds of calcium hypochlorite (bleaching powder) dissolved in 150 gallons of water, with from 3 to 4 pounds of HCl. Work for from 30 to 45 minutes at 140° to 158° Fahr.

For dark shades use, for same quantity of yarn and same amount of water, 6 pounds hypochlorite of calcium and 3 pounds HCl, working for 45 minutes at 122° Fahr.

For use on either dark or light shades take 100 gallons sodium hypochlorite liquor, testing ½° B., with 6 pounds HCl, and treat for 30 minutes at 122° Fahr.

Another method, perhaps better on account of lessened tendency to yellow the fiber, is to treat for 30 minutes at 86° to 95° F. with a bromine solution of from 5 to 8 per cent. strength; but, while this method has a better effect on the strength of the fiber than chlorine, the luster is less brilliant.

In all cases much care is necessary that the operation be not prolonged beyond the specified time, that the temperature be not permitted to rise too high, and that the yarns be turned constantly so as to insure uniform oxidation.

As wool fiber is always more or less discolored by this treatment, it is necessary to bleach before dyeing, aqueous sulphurous acid being best adapted for this purpose. Silk scroop is imparted by charging either before or after dyeing with a solution made up of 120 grains of olive-oil soap per gallon of water, to which is added 50 cubic centimeters of 10 per cent.  $\text{H}_2\text{SO}_4$ .

Temperature of this broken soap bath should be about 122° Fahr.

Another beautiful product of chemical industry is the artificial silk made under the patents of Lehner of Zurich and the *Compte De Chardonnet*, of Bordeaux, which, while not yet demonstrated practical value on account of high cost of pro-



duction compared to silk and various mechanical defects, yet furnish a valuable starting point for what certainly should be a flourishing industry when these defects are overcome.

If cotton be carefully cleansed and passed through a cold bath of strong nitric acid, it is converted into dinitrocellulose without becoming particularly tender or inflammable.

Pyroxylin or gun cotton of the composition  $C_{12}H_{14}(NO_2)6O_{10}$  belongs to the same group of nitrated cellulose compounds, and by means of less concentrated acid we obtain a less nitrated trinitrocellulose known as soluble pyroxylin, which is soluble in alcohol and ether, forming a heavy syrupy fluid known as collodion.

But it is the tetra-nitro cellulose of the same group which forms the basis of the interesting results obtained at different times by Lehner, Chardonnet and others in the artificial silk industry before mentioned.

To produce the remarkable fiber, of which I am able to show typical samples, the pyroxylin, in the form of the tetra-nitrocellulose, is dissolved in a mixture of 38 parts ether and 42 parts alcohol to form a 6.5 per cent. pyroxylin solution.

This solution is introduced into a tinned copper receptacle, from which it is forced by continuous air pressure through a vertical glass tube, ending in a fine capillary orifice, and surrounded by a second glass tube, through which there is a steady flow of cold water.

As soon as the nitrocellulose solution comes in contact with the water it solidifies and may be drawn from the tube as a continuous thread, which, however, is highly inflammable, and must be de-nitrated before it can be safely used.

This is accomplished by first treating with dilute nitric acid, and afterwards with a solution of ammonium phosphate.

The artificial silk thus obtained may now be colored in the same way as ordinary silk, care being taken to avoid boiling, which greatly injures its strength, the temperature of the dye bath being best fixed at or below  $180^{\circ}$  F.

The greatest faults of this cellulose silk lie in its lack of elasticity and its great loss of strength on becoming wet, to which its hygroscopic nature makes it peculiarly liable.

However, I am informed that the use of 15 per cent. of formaldehyde, acetic aldehyde, paraldehyde or other aldehyde derivatives in the solvent used for the pyroxylin will yield a fiber free from these defects, and that the product of the Chardonnet factories is now so treated.

In this connection it might be added that formaldehyde presents to the textile chemist many very useful characteristics, which are being taken advantage of in several processes now in use, and which we will briefly note.

The product formaldehyde was first obtained by Von Hoffman, in 1867, by passing the vapor of methyl alcohol, mixed with air, over finely-divided Pt heated to redness.

It is also formed in small quantity, together with marsh gas ( $\text{CH}_4$ ) and formic acid  $\text{H}_2\text{CO}_2 = \text{HCOOH}$ , by the action of silent electric discharges on a mixture of H and  $\text{CO}_2$ . It may be abundantly obtained at a low cost by the incomplete oxidation of methyl alcohol in a combustion furnace or lamp suitably constructed, and has the formula  $\text{CH}_2\text{O} = \text{HCOH}$ .

Commercial formaldehyde or formalin is a solution of the gas in water, and has come into great prominence through its wide application as a disinfectant. To the textile chemist the property possessed by formaldehyde of rendering gelatine and other bodies insoluble in water suggests many useful applications in dyeing, color printing and finishing.

Besides its use in adding to the strength and durability of cellulose-artificial silk, it may be used in obtaining a silky fiber of considerable strength by the following method:

Gelatine is dissolved in water and a syrupy solution obtained. Then, by a device somewhat similar to that used in the Chardonnet and Lehner processes, it is drawn out into a thread, which is immediately passed into a 4 per-cent. solution of formaldehyde, which renders the fiber insoluble and capable of being woven or knitted in with other fibers.

In this method the dyestuffs would, however, be better added to the gelatine solution, as, after fixation by formaldehyde, the silky fiber obtained would be very difficultly penetrated by the coloring matter, and unsatisfactory results would follow.

A solution of gelatine, prepared in a dark place, with from  $\frac{1}{2}$  to 1 per cent. of bichromate of potash, has also been suggested as a method of obtaining a textile fiber from gelatine, as, owing to the well-known sensitiveness of chrome gelatine to light, it becomes insoluble on exposure, and this derivative has one advantage in being capable of absorbing dyestuffs after fixation. For light colors it is unsuitable, as it always has a dark appearance.

Whether this fiber is destined to hold any practical position in the textile arts is a matter of mere conjecture, as its production so far has not passed beyond the purely experimental stage.

In sizing the backs of velvets and other fabrics, a gelatine solution, colored with any desired dyestuff, is brushed evenly over the surface to be sized, and then the material is either sprayed or brushed over with a 2 per-cent. formaldehyde solution, giving a very permanent and useful size.

In color printing the dyestuffs are added to a gelatine solution of the desired density, and, after the colors are steamed on, the cloth is passed through a 2 per-cent. formaldehyde solution, with the result of fixing the color on the fiber in combination with insoluble gelatine. This reaction has suggested several uses for formaldehyde in printing cotton goods.

In waterproofing it would furnish a uniform coating, which could be cleansed without injury, and capable of being handled very inexpensively. For coating silk or other varieties of fishing lines, it furnishes an enamel which is more permanent and waterproof than any which have so far been used, is entirely without deleterious effect on the fiber, and is already being employed for that purpose, as the samples I have here will testify.

In Lyons, formaldehyde is being extensively experimented with in the manufacture of so-called souple silks, in which the sericine or silk gum is merely softened sufficiently to enable its being handled, and is not boiled off, as is the case with tram and organzine silks.

Formaldehyde has the property of fixing or rendering insoluble this sericine, and is used after the soupling and dyeing

to prevent loss of weight in the different processes to which it is subjected.

There are doubtless other applications in which this insoluble gelatine would be very useful, and another fact, that regarding its property of converting fuchsine and other aniline reds into blues and violets, might not be without hint of possibilities to the colorist.

PHILADELPHIA, March 15, 1898.

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## IN MEMORIAM.

JULES VIENNOT.

On March 11, 1898, the Franklin Institute lost, by death, a most valued member; one who, though unable to attend its meetings regularly, shrank from no sacrifice of his convenience and from no expenditure of the best that was in him, when the Institute had need of his aid.

Jules Viennot was born in Paris, in 1825. His father was the owner of "*Le Corsaire*," one of the leading Parisian political journals of the day.

From 1847 to 1851, the son served in the French army. He was wounded while attacking the barricades of the revolutionists in 1848. After this, and during the "*Journées de Juin*," he was attached, as instructor, to the *Garde Mobile*. After leaving the army he was active in commercial life in France and Belgium. In 1853 he was married, in Brussels, and in the early sixties he came, with his wife and daughter, to America, where he has since resided.

In 1880 he settled in Philadelphia, which has ever since been his home. He became a member of the Franklin Institute in 1881. In 1897 he was made a Director of the *Société de Bienfaisance Française*, of which he had been a member for several years.

Mr. Viennot was especially active in connection with both the Electrical and the Novelties Exhibitions of the Institute, and his untiring activity in securing proper newspaper recognition contributed, in no small degree, to the success of the former of those enterprises.

*(Jour. Frank. Inst., Vol. CXLV., June, 1898.)*



*J. Kennerly*

[1825-1898.]

In 1894 he received from the French government a decoration in recognition of his hospitable services in behalf of technical and other visitors from France, particularly during the World's Fair in Chicago in 1893, when he devoted himself most unsparingly to the reception and entertainment of a large body of members of the Société des Ingénieurs Civils de France. Members of the Franklin Institute and of the Engineers' Club of Philadelphia will long bear in affectionate remembrance his untiring efforts in behalf of their guests at that time.

During his latter years Mr. Viennot was engaged in building up a prosperous business, in which he represented the advertising interests of his clients, placing their announcements in the various technical and trade papers, advising them in their selection of such journals, and attending to the accounts growing out of those transactions. Such was his zeal and ability in the interests of his clients, that he found himself entrusted with the advertising business of the Baldwin Locomotive Works, the Southwark Foundry and Machine Company, Merchant & Co., and many others of the most prominent engineering and mercantile firms and corporations in Philadelphia and in other cities.

It is easy thus to sketch, in brief outline, what Mr. Viennot was in his outer life; but how impossible to say what he was to his friends. Never was the dread name of "Advertising Agent" more richly graced than by Jules Viennot, gentle man and gentleman, the best conditioned and unwearied spirit in doing courtesies. Combining, in exquisite harmony, all the delicacy of genuine French politeness, with a deep and clear knowledge of affairs, the perfection of modesty, and a rugged, old-fashioned, human thorough-honesty, his personality was a thing apart, and not only won him friends, but endeared him to them as it is the lot of but few to be.

In his kindly smile shone the brightness and warmth, in his delicious broken English sounded the truth and nobility, of the French character. As a compatriot has said, he was one of those Frenchmen who make their country beloved abroad.

For the last time he has brightened our threshold. For the last time he has left us the better for his visit. For the last time he has said—as he was only too ready to say—  
“And now, I will go. Good-bye.” J. C. T., Jr.

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JAMES FOSTER SMITH.

James Foster Smith, of Reading, Pa., one of the oldest civil engineers in the United States, entered into rest on Monday morning, January 31, 1898, in his eighty-fifth year. He sprung from Scotch-Irish ancestry. His grandparents came to America about the year 1783, settling in Pittsburgh; a portion of that early band of Covenanters, the impress of whose sturdy character is still so plainly manifest throughout Western Pennsylvania.

Mr. Smith was born in Pittsburgh, on Christmas Day, 1813. In 1822 his parents moved to Blairsville, Pa., where he received a rudimentary education in the village school; but the necessity of self-support terminated even these meager educational advantages at the early age of twelve years. During such leisure as he was able to spare from daily work he devoted himself to study. His natural inclination carried him into the channels of civil engineering just at the time when the Pennsylvania Canal and other public improvements were in course of construction, and long before a college of engineering was known in America.

In 1831, at the age of eighteen, he entered the service of the Portage Railroad Company as a rodman under the late Solomon W. Roberts. In 1836 he became connected with the Catawissa Railroad as Assistant Engineer under the late Edward Miller, Chief Engineer, but, owing to the financial difficulties of the company, this engagement was of short duration. The years 1837-1838 he spent in the service of the Morris Canal Company as Engineer-in-Charge, during which time he designed and built, among other works, the tide lock at the outlet of the canal in Jersey City, which is still in use.

Returning, in 1839, to the Catawissa Railroad, he spent the following two years upon that work as principal Assistant

(*Jour. Frank. Inst.*, Vol. CXLV., June, 1898.)



JAMES FOSTER SMITH.

[1813-1898.]



Engineer. In 1840, he designed the high trestles for which the Catawissa line for years past has been and still is celebrated. The wooden trestles, varying in height from 53 to 129 feet and in length from 600 to 1,100 feet, were the first of the kind in the country. The plans were copied into the leading engineering journals of the day, and copies of the same were also furnished to the engineers of the New York and Erie Railroad, and were adopted by the late Silas Seymour, C.E., as the design of the original Portage Viaduct over the Genesee River. The model of these trestles, which are believed to have been the beginning of high structural works in timber, and essentially the same as now followed in similar constructions of iron and steel, is now standing in the hall of the Franklin Institute. The actual woodwork of this model was made by Mr. Smith, and the bolt work by the late Ellerslie Wallace, M.D., Dean of Jefferson Medical College, then an Assistant Engineer in the Catawissa Railroad. The years 1841-1842, he spent with the New York and Erie Railroad Company as cashier of the Eastern Division, with headquarters at Piermont, N. Y., during which service Mr. Smith originated and put into use the blank forms used in the inward- and outward-bound freight business of the road at that time.

In 1843, Mr. Smith entered the service of the Schuylkill Navigation Company, first as Superintendent of the Lower Division, serving in that capacity, under the presidency of Solomon W. Roberts, until 1845, when the enlargement of the works was put under contract, and Charles Ellet, C.E., having assumed the presidency of the company, he was appointed Resident Engineer, and had charge of the reconstruction of the canal and slack-water navigation between Philadelphia and Reading, completing the same in 1846.

After the disastrous flood of September, 1850, he was elected, by the Board of Managers, Chief Engineer of the company, and proceeded to rebuild the damaged works, making many changes and improvements to defend them against future floods, and to increase their carrying capacity.

He filled the position of Chief Engineer with the Schuylkill Navigation Company under the presidency of Frederick Fraley,

Esq., until 1870, and subsequently with the Philadelphia and Reading Railroad Company until the year 1875 (the Susquehanna and Tidewater Canals having been added to his charge in the meantime), when he relinquished the more active duties of his professional life, but still continued to serve as Consulting Engineer until 1885, when he retired from engineering work.

During the thirty-two years of active service with the Schuylkill Navigation Company, Mr. Smith designed and constructed many important hydraulic works, noticeably most of the existing dams upon the Schuylkill River, built with square back and perpendicular sheet piling instead of the prevailing rafter shape. A type of these structures is the present Fairmount dam at Philadelphia and the great dam, 6,843 feet long, across the Susquehanna River at Columbia. The design has been largely followed in this country and in Europe as being the best to successfully resist floods and the most economical to maintain. Other important works were the extensive shipping landings of the company at Schuylkill Haven and a system of wharves with automatic coal-transferring machinery at Greenwich Point, on the Delaware River, the first of the extensive wharves at that location.

He also constructed extensive aqueducts of stone and wood and many works requiring difficult cofferdamming in such situations as to call for the highest skill of the hydraulic engineer. After his withdrawal from the engineering service of the company, in 1883, Mr. Smith was elected President of the East Pennsylvania Railroad Company, serving for one year, when he retired to private life and the enjoyment of well-earned rest.

Mr. Smith became a member of the Franklin Institute in 1848, and maintained his membership continuously until his death. Although never conspicuously active, he manifested much interest in the work of the Institute, and was a frequent attendant at its meetings. He contributed to its *Journal* a valuable paper on "The Future Water Supply of the City of Philadelphia" (*vide Jour. Frank. Inst.*, vol. cviii, 236, *et seq.*), in which he ably advocated the proposition for a gravity supply by aqueduct from the Perkiomen.

In the death of the subject of this sketch the engineering profession and the Franklin Institute lose a valued member and the community a useful citizen. W.

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### ERRATUM.

ART.: CREHORE AND SQUIER SYNCHRONOGRAPH.

#### DISCUSSION.

In Mr. Delany's contribution, May impression, page 371, 12th line, after the word . . . periods, it should read:

"And signals may be recorded at a higher speed provided the tapes of ordinary telegraphic use can be made as synchronous with the generator as permanently fastened pieces of paper mounted with mathematical precision on a circuit wheel, but so far as chemical recording is concerned, even with this arrangement and the utterly impracticable character of received signals, there can be no increase of speed."

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### CORRESPONDENCE.

#### A WARM WINTER.

##### *The Committee on Publications :*

GENTLEMEN :—It is evident that we have passed through an unusually warm season, and it is reasonable to inquire how much the temperature has varied from that of an average winter. The Weather Bureau follows the business man's method by making comparisons between the records for calendar periods. The seasons, however, do not correspond to months or years, and, in fact, are so indefinite when mentioned in prose or poetry, that the days of their beginning or ending cannot be stated. Hence there is no such record as that of a season's temperature, though to people generally the subject is one of much interest and speculation.

In our latitude the seasonal or normal movement of temperature lags behind the sun's apparent motion north and south of the equator, the extremes not being reached until about the 22d of January and July, or in each case about one month after the solstice, while midway between the extremes the normal temperature of the day crosses the normal of the year about one month after the equinoxes. These dates of crossing may well be called the equi-normal dates, and mark the divisions of the warm and cold halves of the temperature year.

It is proposed to give a measurement of these definite temperature periods from the U. S. Weather Bureau's local weather reports, so familiar to the readers of the daily newspapers. Extracts from reports for two equi-normal dates are given below :

U.S. WEATHER BUREAU, Philadelphia, Pa., Friday, October 22, 1897.	U.S. WEATHER BUREAU, Philadelphia, Pa., Friday, April 22, 1898.
Max. tem. (2.00 P.M.) 54 Min. tem. (Mid., 22-23) 48	Max. tem. (1.00 P.M.) 65 Min. tem. (5.00 A.M.) 45
Mean temp. . . . 51 Normal temp. . . . 54	Mean temp. . . . 55 Normal temp. . . . 54
Deficiency of temperature to day, 3.	Excess of temperature to-day, 1.
Excess of temp. since Oct. 1, 70.	Accumulated defic'y of temp. since April 1, 11.
Accumulated excess of temp. since Jan. 1, 248.	Accumulated excess of temp. since Jan. 1, 424.

It will be seen that the sum of the maximum and minimum temperatures divided by two is taken as the mean of the day. The average of the daily means for all the days of any particular date, since the station was established is considered as the normal of that day. For the days selected, the normals were 54°, or the same as the normal of the whole year. The difference between the mean and normal is the excess or deficiency of temperature, and the net accumulations of these differences since the first day of the year and the first day of the month, are stated in the reports.

On the 22d of April, 1897, the accumulation of excesses was 126°, and by the 22d of October, 1897, the excesses had accumulated, as shown by the report, to 249°, so that the accumulation for the warm half-year between these dates was 123°. By the 31st of December there was a further accumulation of 148°, and, this added to the 424° accumulated since the 1st of January, as appears in the report of April 22, 1898, gives a sum of 572° for the accumulation of warmth for the cold-half of the year.

If we divide the total for the half year by 182, the number of days in the period, we find that there was an average daily excess of 3½ degrees. The further character of this winter half-year is shown by the figures for first quarter to January 22d, when the accumulation of excess was 255°, while after that date there was a further accumulation of 317°. The greatest accumulation was reached March 30th, when the total excess was 584°.

If readers will have in mind that the accumulation of excesses on April 22d was 424°, they can easily reckon from the daily reports, the progress of the summer half-year, and by taking bearings again on October 22d the progress of next winter's half-year may also be noted from day to day. In this latitude the winter half-years are of special interest to housekeepers, for they correspond closely with periods for heater fires.

In the table below comparison is made between the accumulated temperatures of the half-years for eleven years.

Warm Half-Year, from April 23 to Oct. 22, inclusive.	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897
Accumulated excess of temperature . . . .	159			93	27	109		177	139	112	123
Accumulated defi- ciency of temperature		353	26				11				

Cold Half-Year, from Oct. 23 to April 22, inclusive.	1887-8	1888-9	1889-90	1890-1	1891-2	1892-3	1893-4	1894-5	1895-6	1896-7	1897-8
Accumulated excess of temperature . . . .		396	951	234			292		125	287	572
Accumulated defi- ciency of temperature	127				17	442		338			

As a further standard of comparison, it may be stated that the winter of 1889-90 was much the warmest of any shown by the Philadelphia records for seventy-two years past.

Respectfully,

HENRY GAWTHROP.

## Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, May 18, 1898.*]

HALL OF THE FRANKLIN INSTITUTE,  
PHILADELPHIA, May 18, 1898.

The President, MR. JOHN BIRKINBINE, in the chair.

Present, 210 members and visitors.

Additions to membership since last report, 5.

Mr. Wm. F. Roberts supplemented his communication of last month, on the carbon dioxide engine, by a description of a condensing engine of the same type. An exhibition of the operation of this apparatus, which had been contemplated, was deferred until the June meeting.

Mr. W. S. Ryan, of the Philadelphia Museums, made an extemporaneous address on the Philippine Islands, giving some account of the Islands, their inhabitants, and the administration of the group by the government of Spain. Prof. Wm. P. Wilson, Director of the Museums, supplemented these remarks with an account of the productions of the Islands, and statistics of their trade and commerce.

Mr. E. D. Meier, engineer-in-chief of the Diesel Motor Company, New York, read a paper on the Diesel Motor, illustrating the subject with the aid diagrams. (Referred for publication.) The subject was referred, for investigation and report, to the Committee on Science and the Arts.

Adjourned.

WM. H. WAHL, *Secretary*.

## COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, May 4, 1898.*]

PROF. L. F. RONDINELLA in the chair.

Reports on the following subjects were considered :

*Severy Impression Process*.—Melvin L. Severy, Boston, Mass. Passed first reading.

*Hard-drawn Copper Wire*.—Thos. B. Doolittle, Branford, Conn. Passed first reading.

*Improvements in X-ray Tubes*.—H. Lyman Sayen, Philadelphia, Pa. Passed first reading.

*System of Aërial Navigation*.—H. H. Fisher, Corpus Christi, Tex. Passed first reading.

*Pneumatic Balance Lock*.—Chauncey N. Dutton, New York. Passed first reading.

*Compound Locomotive*.—Clifton L. Reeves, Trenton, N. J. On the strength of a protest from applicant, this subject was reconsidered, and the report and and protest were referred to a new sub committee.

The following reports were adopted :

*Improvements in Turnbuckles*.—E. W. Merrill, Brooklyn, N. Y.

ABSTRACT.—The claims of applicant are based on a patented procedure (see U. S. Letters-patent No. 462,499, November 3, 1891), which consists in rolling the general shape of the turnbuckle from a bar of steel in suitably shaped rolls. This operation leaves a fin in the centre between the shanks, which is subsequently punched out. By a third operation, the bosses are swaged up in order to bring up the inner edges of the bosses, which had a rounded contour after the rolling operation. This third operation, upon which the applicant lays special stress, is held in the report to be quite useless, as the extra metal thereby incorporated in the turnbuckle neither adds to its strength nor improves its form.

The report concludes with the statement that the operations described in the patented process of applicant present no specially novel or valuable features. [Sub-Committee.—A. Falkenau, Chairman; Wilfred Lewis.]

*Swivel-Loom*.—Herman Willmunder, Philadelphia.

ABSTRACT.—This invention is an attachment to a loom adapted to the purpose of weaving into the fabric small figures (such as flowers), without carrying the material of which they are made entirely across the fabric, and without using warp threads for the figures. Such an arrangement is known in the art as a "swivel-loom."

The report makes reference to previous attempts to weave shaded figures on the face of cloth, which was done formerly by the use of hand-loom, requiring the most skilled weavers, and more recently on power-loom by the Jacquard mechanism. The report concludes that this inventor has considerably improved and simplified this last-named device for accomplishing the purpose intended. An intelligible description of the attachment in detail is not possible without the aid of illustrations. The Scott award is recommended. [Sub-Committee.—G. Morgan Eldridge, Chairman; John Shinn, Robert B. Goodyear.]

*Abatement of the Smoke Nuisance*.—Referred by the Institute.

ABSTRACT.—The Committee recommends certain conclusions to be recommended to the Board of Managers for embodiment in the draft of an ordinance to be transmitted to the Bureau of Health. [Sub-Committee.—H. W. Spangler, Chairman; Wm. M. Barr, John Birkinbine, Alex. E. Outerbridge, Jr., Coleman Sellers.]

*Ejector for Fluids*.—W. B. Hollingshead, Bronxville, N. Y.

ABSTRACT.—This invention has been previously described in these abstracts (see the *Journal*, cxliii, 454), to which reference is made.

The present report is the outcome of a reconsideration of the case on an appeal by applicant, and revises the conclusions of the previous one.

It is found, by practical tests for a period of three months, under the unfavorable conditions of using unfiltered Schuylkill water, that the device was demonstrated to be reliable.

As an inexpensive and easily-cared-for apparatus for the automatic distribution of disinfecting materials soluble in water, the device is approved. The Edward Longstreth Medal of Merit is awarded. [*Sub-Committee*, H. R. Heyl, Chairman ; John G. Bullock.]

*Arrangement of Cylinders for Balanced Locomotives.*—J. H. Dunbar, Youngstown, Pa.

ABSTRACT.—This device is an arrangement of two cylinders in tandem on each side of a locomotive, for the purpose of counterbalancing the reciprocating parts without weights in the driving-wheels. It consists of a cylinder, located as usual on each side of the engine, with its piston-rod, crosshead, and connecting-rod connecting to the crank-pins. In addition, another cylinder is placed directly in front of the first cylinder, with its piston-rod connected with one end of a lever arm, or walking-beam, pivoted at or near its centre, in a support or bracket in front of or below this cylinder, the opposite or lower end of the walking-beam being connected by a rod extending backward to the crosshead of the first cylinder.

By this arrangement, the applicant claims that the momentum of the reciprocating parts is equalized by the moving of the pistons in opposite directions.

The committee fails to discover this result, but finds that the additional parts would increase the amount of counterbalance needed in the driving-wheels, and, furthermore, that the mechanical arrangement as set forth is such as to be impracticable for locomotive use. [*Sub-Committee.*—J. Logan Fitts, Chairman ; Henry F. Colvin, Arthur J. Rowland.]

*Check-Funch.*—G. O. Brosnahan, Pensacola, Fla.

ABSTRACT.—The work of this punch consists in making a printed impression of the figures and symbols in the form of a series of dots, resembling those actually punched out of the paper (by actual perforation) in the machines formerly in common use by the United States Government and by financial institutions generally.

Those machines which perforate the paper by means of round holes, however, have practically been discarded for those in which the perforation of the paper includes the general outline of the figures and symbols. In this form of perforation there appears to be no serious danger that the figures or symbols can be fraudulently altered without detection.

A machine that simply prints what we generally write, the investigating committee believes, does not present, in this case, any advantage, while the cutting out of the paper is an extra safeguard against fraud ; also, the machine of applicant is more costly and complex than those in use producing practically the same result. [*Sub-Committee.*—Edward F. Moody, Chairman.]

## SECTIONS.

**ELECTRICAL SECTION.**—*Special Meeting* held Tuesday, March 29, 1898. Present 50 members and visitors. Mr. W. E. Harrington, President, in the chair. A paper on "The Substitution of Electricity for Steam on Suburban Roads," which had been announced as the special business of the meeting, was postponed at the request of Dr. Louis Duncan, the author.

The meeting thereupon engaged in an impromptu discussion of the subject of Rail-bonding, which was participated in by Messrs. Pepper, Reed, Hering, Brogg, and Harrington.

The drift of opinion was to the effect that the commercial forms of bonds making contacts through holes in the web of the rails were impractical and the form of bond consisting of copper-plates making contact with the sides of the web of the rail and using flexible solder or other metallic connection appeared to be the best adapted, mechanically and electrically, for the intended service.

WM. WARR, *Secretary*.

**MINING AND METALLURGICAL SECTION.**—*Stated Meeting* Wednesday, May 11, 1898, Mr. A. E. Outerbridge, Jr., in the chair. Present 29 members and visitors. Mr. William Tatham presented a paper on "Gold Mining in Georgia," giving a brief sketch of the character and extent of the gold-bearing deposits and of their past and present development, the proper methods of treating the ores, etc. Discussed by Messrs. Outerbridge, Garrison, Wahl, and the author. (Referred for publication.)

Mr. Guillaum H. Clamer read a paper entitled "On the Micro-Structure of Bearing Metals." The subject was very thoroughly treated, and embodied the results of numerous original observations. The paper was illustrated by means of lantern projections of photographic enlargements of numerous typical specimens of micro photographs. The paper evoked an animated discussion, participated in by Messrs. Christie, de Benneville, Outerbridge and the author. (Referred for publication.) Adjourned.

JAMES B. DE BENNEVILLE, *Secretary*.

**CHEMICAL SECTION.**—*Stated meeting* held Tuesday, May 17, 1897, President, Lee K. Frankel, in the chair.

Dr. Harry F. Keller presented a preliminary communication on "The Synthetic Preparation of the Hydroxy-acids." Discussed by Dr. W. C. Day, Mr. C. J. Reed, and the author.

Dr. Wm. C. Day made an informal communication on the artificial preparation of an asphaltum-like substance, possessing substantially the same composition as gilsonite, and analogous physical properties. The method followed consisted in subjecting to destructive distillation a mixture of fish and resinous pine chips, and passing the distillate through a red-hot iron tube. Discussed by Mr. Jos. Richards, Mr. C. J. Reed, and the author.

Adjourned.

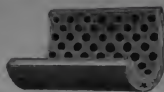
LYMAN F. KEBLER, *Secretary*.



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